ABSTRACT

Edible oil constitutes an important component of food preparation in Indian households. It is evident from research studies that Gujarati population consumes highest amount of edible oil in our country. Frequent/high intake of fried foods may be one of the reasons for increased prevalence of nutrition related non-communicable diseases (NR-NCDs). However, there is a need to document the frequency of fried foods intake by Gujarati households.

Frying makes food flavorful, varied and rich. Fried foods exhibit various quality characteristics such as unique appearance, texture, odor etc. Oils and fats used for frying gradually undergo certain chemical changes commonly known as oxidation, hydrolysis and polymerization. In India major portion of vegetable oils are used for frying foods. Deteriorated oils are not only insidious cause of cancers, hypertension and coronary heart diseases but also results in low nutritional quality and inferior sensory characteristics. Sensory assessment of foods fried in repeated heated oils may limit number of fryings in reused oil. Most of the studies have been carried out with intermittent time periods of 80-90 h and little attention is given to researches where the intermittent frying time matches the duration used at households and restaurants level.

Thus the present study was undertaken in 5 phases with a broad objective of studying the "Occurrence of chemical and sensory changes during intermittent frying of french fries and bhajias in groundnut and cottonseed oil and studying the association between the fried food intake by the Gujarati housewives and non-communicable diseases". As part of extension activity of research on fried foods a case study was undertaken to study the prevailing food safety and frying practices in Jan aahar- A Government run food outlet at Vadodara railway station and developing the Nutrition Health Education (NHE) material on intake of edible oil, types, and on choices of oils for healthy living and correct practices of using edible oil for frying purposes and its storage.

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Appendix 11.1
Questionnaire

GENERAL PROFILE-

1. Name: ____________________ 2. Address: ______________________________

3. Age: ________ 4. Occupation: __________________________

5. Family Monthly Income: ______ 6. Family Members: _______________________

7. Marital status: a) Single ( ) b) Married ( ) c) Divorce ( )

d) Widow ( )

8. Education Level: a) Illiterate ( ) b) Primary ( ) c) High school ( )

d) Higher Secondary ( ) e) Graduate ( ) f) Post-Graduate ( )

9. Activity pattern: a) Moderate ( ) b) Sedentary ( ) c) Heavy ( )

10. Exercise: a) Yes ( ) b) No ( )

11. If yes: a) Daily ( ) b) Weekly ( ) c) < 3 times in a week ( )
d) Occasionally ( )

12. **What type of exercise?**

Exercise type	Daily	Weekly	Occasionally	Never
Yoga				
Brisk walking				
Jogging				
Cycling				
Swimming				

13. **Anthropometric Measurements:**
   a) Weight: (kg) ______________________
   b) Height: (cms) ______________________
   c) BMI – Weight(kg)/Height(m^2) ________________

MORBIDITY PROFILE		Since when	levels
14. Do you have Diabetes?	Yes / No		
15. Are you suffering from Hypertension?	Yes / No		
16. Are you suffering from any chronic degenerative disease?	Yes / No		
17. Have you ever suffered from liver disease?	Yes / No		
18. Do you have gastrointestinal problems?	Yes / No		

FOOD HABITS

19. **Likes and Dislikes- Foods preferred during a meal and their frequency-**

Cooking method	Daily	2-3 times a week	Weekly	Fortnightly	Monthly	Rarely	Yearly
Steamed							
Boiled							
Sautéed							
Shallow fried							
Deep fried							
Grilled							
Roasted							

20. **Type of OIL used for cooking:**

Type of oil	Daily	2-3 times a week	Weekly	Fortnightly	Monthly
Saturated					
Ghee					
Butter					
Cheese					
Vanaspati ghee					
Other					
Monounsaturated					
Groundnut oil					
Palmolein					
Mustard oil					
Rice bran oil					
Other					
Polyunsaturated					
Cottonseed oil					
Corn oil					
Sunflower oil					
Safflower oil					
Soybean					
Other					

21. **Total amount of oil stored/purchased in a:** (amounts in liters (Approx amts)

Week ____________ Month___________ Year________

22. **How often you prepare fried food at home?**

Deep-Fried Foods	**Daily**	**2-3 times a week**	**Weekly**	**Fortnightly**	**Monthly**	**Rarely**	**Yearly**
Chips/ French fries							
Samosa/Cutlets/ Breadrolls / Kachori							
Bhajia/Pakoda							
Vada/Meduvada/ Mathri/Namakpara							
Undia							
Chiwda/ Chana dal/Moong dal							
Other Specify-							
Shallow fried-							
Parantha							
Pav bhaji							
Bhalle							
Sev Khamni							
Burgers/ Hotdogs							
Cheela							
Other Specify-							
Sweets-							
Gulabjamun							
Jalebi							
Mysorepak							
Boondi laddo							
Other specify-							

23. **How often you purchase fried foods from the market?**

Deep-Fried Foods	**Daily**	**2-3 times a week**	**Weekly**	**Fortnightly**	**Monthly**	**Rarely**	**Yearly**
Chips/ French fries							
Samosa/Cutlets/ Breadrolls / Kachori							
Bhajia/Pakoda							
Vada/Meduvada/ Mathri/Namakpara							
Undia							
Chiwda/ Chana dal/Moong dal							
Other Specify-							
Shallow fried-							
Parantha							
Pav bhaji							
Bhalle							
Sev Khamni							
Burgers/ Hotdogs							
Cheela							
Other Specify-							
Sweets-							
Gulabjamun							
Jalebi							
Mysorepak							
Boondi laddo							
Other specify-							

24. **Do you like to dine in restaurants/parties? If yes, how often:**
a) Daily ( ) b) Weekly ( ) c) Once in a month ( )
d) Occasionally ( ) e) Never ( )

25. **What type of food you prefer most during eating outside?**
a) Steamed ( ) b) Boiled ( ) c) Sautéed ( )
d) Shallow fried ( ) e) Deep fried ( ) f) Grilled ( )
g) Roasted ( )

26. **How often you travel?** ______________________________

27. **What type of food you prefer during traveling?**
a) Homemade ( )
b) Ready to eat ( )

Type of cooking method
____

28. **Are you?**
a) Vegetarian ( ) b) Non-vegetarian ( ) c) Ovo-vegetarian ( )

29. **Type of cooking method preferred for egg-**
a) Boiled ( ) b) Shallow fried ( ) c) Deep fried ( )
d) Other ( )

30. **Specify the cooking method preferred for preparing non-vegetarian foods-**
a) Boiled ( ) b) Shallow fried ( ) c) Deep fried ( )
d) Other ( )

FRYING PRACTICES-

31. How many times you use fried oil for refrying? ______________________

32. When you consider the fried oil as not fit for consumption?

a) After 1st frying ( ) b) After 2nd frying ( ) c) After 3rd drying ( )
d) After 4th frying ( )

33. What do you do with left over fried oil?
a) add more fresh oil for refrying ( ) b) discard fried oil ( )
c) use fried oil for any other purpose( ) d) Refry the same oil without adding more ( )
e) use for sautéing and other cooking purposes ( )

34. Changes noticed during frying-
a) Gumming ( ) b) Thickness ( ) c) Color changes ( )
d) Other ( )

35. Practice of keeping/storing fried oil-
a.) Filtered ( ) b.) Without filtration ( )

36. Type of utensil used for frying-
a) Iron ( ) b) Stainless steel ( ) c) Teflon ( )
d) Hindalium ( )

FRYING AND STORAGE KNOWLEDGE
Please tick the correct answer:

37.	Recommended amount of oil for per person/day? a) 10-20g ( ) b) 20-30g ( ) c) 40-60g ( ) d) 60-80g ( ) e) No limit ( ) f) do not know ( )	
38	Are you aware that higher fat intake causes health problems?	Yes / No
39.	Do you know the harmful effects of excess fried food consumption?	Yes / No
	If yes, perception about ill effects of consuming excessively fried foods: a) Obesity ( ) b) Heart disease ( ) c) Gastrointestinal problems ( ) d) Any other ( )	
40.	Once fried oil can be refried again or not?	Yes / No
41.	If yes, for how many times: a) After 1st frying ( ) b) After 2nd frying ( ) c) After 3rd drying ( ) d) After 4th frying ( )	
42.	Do you know that refrying causes thickening in oil?	Yes / No
43.	Do you know that fried oil should be filtered before storage?	Yes / No
44.	Why fried oil should be filtered? a) To remove small fried particles ( ) b) To remove dust ( ) c) To clean oil ( )	
45.	Does the fresh oil undergo any changes upon storage?	Yes / No
46.	If yes, state the changes- a)change in color ( ) b) foul odor ( ) c) oil thickens ( ) d) any other ( )	
47.	Have you ever noticed the oil manufacturing date before buying?	Yes / No
48.	What type of container should be used for storing the oils: a) Plastic transparent jars ( ) b) Glass jars ( ) c) Steel jars ( ) d) Plastic containers (opaque) ( )	
49.	Do you know about the oil blends?	Yes / No
50.	Are blended oil good for health?	Yes/No
51.	What are oil blends? a) Combination of one or more oil ( ) b) Combination of two or more than two oils ( ) c) Type of oil ( ) d) Do not know ( )	
52	Do you know about trans fat is?	Yes / No
53.	If yes, a) form of fat which is harmful to health ( ) b) form of fat which is beneficial to health ( ) c) form of fat which adds taste to the diet ( ) d) form of fat which has no effect on health ( ) e) any other ( )	
54.	Name the sources of trans fats a) baked, fried foods and edible oils ( ) b) fruit juices ( ) c) vegetables ( ) d) do not know ( )	

Appendix 11.2

SENSITIVIY THRESHOLD TEST

Name: ________________ **Date:** ___________

You are provided with a series of containers having solutions with increasing concentration of one of the tastes qualities (sweet and salty). Please start with Sr. No.1 and continue with the rest.

RETASTING OF ALREADY TASTED SOLUTIONS IS NOT ALLOWED.

Describe the taste or give intensity scores.

Use the following intensity scale:

0= None or the taste of pure water

?= Different from water, but taste quality not identifiable

x= Threshold very weak (Taste identifiable)

1= Weak Taste

2= Medium

3= Strong

4= Very strong

5= Extremely strong

Set no.	Description of taste and feeling
1	___________
2	___________
3	___________
4	___________
5	___________
6	___________

Signature

Appendix 11.3
SCORE CARD FOR PRODUCT EVALUATION

PANELIST No. - ____________ **DATE-** ___________________

NAME- ____________________ **PRODUCT-** _______________

You are being given the samples of fried product. Kindly grade the samples (SC and SG) for the sensory attributes listed under each parameter.

You are requested to score the product using the following scale:

1-Dislike extremely **2**-Dislike very much **3**-Dislike slightly **4**-Neither like or dislike **5**-Like slightly **6-**Like very much **7**-Like extremely **8-**Like very much **9**-Like extremely

ORGANOLEPTIC EVALUATION

	Attributes															
Sample No.	**Appearance**		**Color**		**Crispness**		**Greasiness**		**Flavor**		**Taste**		**Odor**		**Overall acceptability**	
	SC	**SG**	**SC**	**SG**	**SC**	**SG**	**SC**	**SG**	**SC**	**SG**	**SC**	**SG**	**SC**	**SG**	**SC**	**SG**
0																
6																
11																
16																
21																

COMMENTS: - ____

____

Signature

Appendix 11.4a

Comparison of peroxide value between CSO and GNO at intermittent intervals of french fries frying

Duration of frying	CSO	GNO	't'
0 h	9.9±3.89	4±0.84	**2.92***
5 h	14.9±0.84	15.3±3.57	**0.26**^{NS}
10 h	11.4±0.97	19.5±2.57	**5.88****
15 h	13.5±1.81	17.9±4.08	**2.00**^{NS}
20 h	13.4±2.90	16.2±1.68	**1.67**^{NS}
25 h	19.6±2.08	16.5±2.72	**1.80**^{NS}

Comparison of p-anisidine value between CSO and GNO at intermittent intervals of french fries frying

Duration of frying	CSO	GNO	't'
0 h	9.1±0.61	0.73±0.77	**19.96*****
5 h	93.3±0.43	53.6±2.72	**28.86*****
10 h	144.3±0.93	88.2±1.60	**61.08*****
15 h	191.0±1.90	103.1±1.49	**72.85*****
20 h	213.4±2.85	137.1±1.86	**44.75*****
25 h	231.9±2.2	127±1.63	**69.66*****

Comparison of TPC between CSO and GNO at intermittent intervals of french fries frying

Duration of frying	CSO	GNO	't'
0 h	1.9±0.01	1.1±0.01	**104.65*****
15 h	6.8±0.02	3.4±0.02	**159.33*****
25 h	11.5±0.01	10.6±0.07	**17.21****

Appendix 11.4b

Comparison of peroxide value between CSO and GNO at intermittent intervals of bhajias frying

Duration of frying	GNO	CSO	't'
0 h	8.4±0.25	13.9±0.40	**23.04*** **
5 h	13.1±1.28	9.1±0.62	**5.64** **
10 h	8.5±0.40	8.1±0.08	**1.70NS**
15 h	9.4±0.45	6.9±0.49	**7.55*** **
20 h	9.6±0.68	7.2±0.48	**5.84** **
25 h	9.5±0.57	10.4±0.15	**3.04* **

Comparison of p-anisidine value between CSO and GNO at intermittent intervals of bhajias frying

Duration of frying	GNO	CSO	't'
0 h	0.6±0.28	8.7±0.27	**41.34*** **
5 h	61.5±1.42	62.1±0.64	**0.72NS**
10 h	82.6±3.32	85.5±3.53	**1.17NS**
15 h	91.9±1.09	109.2±1.74	**16.89*** **
20 h	95.6±0.77	123.2±3.17	**16.91*** **
25 h	108.8±2.14	129.9±4.28	**8.80*** **

Comparison of TPC between CSO and GNO at intermittent intervals of bhajias frying

Duration of frying	CSO	GNO	't'
0 h	4±0.07	3.1±0.02	**22.88*** **
15 h	7±0.10	9.2±0.27	**15.49*** **
25 h	14.4±0.69	7.6±0.19	**19.06*** **

Appendix 11.5

Questionnaire for 'JANAAHAR'

1. General Information

a) Name ________________ **b) Age** _________ **c) Sex** _____

d) Education level:

i) Illiterate ( ) ii) up to primary ( ) iii) Primary to HS ( )

iv) HS to Graduate ( ) v) Above graduate ( )

e) **How many hours you work from morning till night?**

i) up to 8 hrs ( ) ii) 8-12 hrs ( ) iii) above 12 hrs ( )

f) Wages monthly:

i) Below 1500 ( ) ii) 1500-2000 ( ) iii) 2000-2500 ( ) iv) 2500-3000 ( )

v) Above 3000 ( )

g) Which work you are doing:

i) Cook ( ) ii) Waiter ( ) iii) Cleaner ( ) iv) Supervisor ( )

h) Number of people employed in the unit ________________

i) How many people are catered in a day _________________

j) **Have you ever trained for food safety training: Yes ( ) No ( )**

2. Observation table for unit and cooking staff

Sr. No	Practices	Unsatisfactory	Average	Satisfactory
	Personal Hygiene of the staff			
1	The food handlers have uniform, head gear, apron and towel			
2	Overall appearance of food handlers is clean			
3	Washing with soap after toilet/personal work			
4	Dresses of the employees are clean			
5	Nails of the workers are clean			
6	No smoking, gutka eating and tobacco chewing by the staff while working			
7	Dry hands with separate towel/napkins for the same			

8	Use of mask while cooking and serving			
9	Whether health check up was done before or during service			
	Food hygiene			
1.	Use of running water for washing of raw materials			
2.	Sorting and removal of unwanted portion, ingredient before cooking and processing			
3.	Chopping and peeling only after proper washing			
4.	Use of clean knifes, cutter and chopping board for vegetables, salads			
5.	Every item is covered before cooking, during cooking and after cooking			
6.	The restaurants had separate store for raw materials			
7.	Spices, food ingredients were clean and labeled			
8.	Take away service available in aluminum foil, butter paper, green leaf or dry leaf cups/plates			
9.	Avoiding plastic/ceramic vessels for eating, serving, drinking, storage etc.			
10.	Use of stainless steel knives			
11.	Use of chilling facilities/refrigerator for storage			
12.	Cooked food was stored in stainless steel vessels			
13.	All serving and dining vessels were covered and kept at a dry place			
14.	Running water was provided for washing and cooking			
	Unit hygiene			
1	Commercial detergents are used for washing utensils			
2	Utensils are washed immediately after use			
3	Clean cloth is used for moping of tables, counters etc.			
4	Presence of neat and clean wash basin			
5	Wash basin has running tap water facility			
6	Wash basin has soap/liquid soap			
7	Wash basin has clean and dry towels			
8	Food service unit is dust, dirt and smoke free			
9	Use of smokeless fire and fuel for cooking			
10	The kitchen had exhaust fan, ventilators and chimney			
11	Hot water/ geysers facility is available			
12	Water purifier facility was provided for drinking water			
13	Service counter had glazed surface			
14	Service counter was cleaned frequently			
15	Washing and mopping of floor after every shift			
16	Detergent and tools used for washing of kitchen top, ground floor, sinks, stores etc. after every shift			

17	White wash of walls, roofs, stores, kitchen etc.			
	Environmental hygiene			
1	Dining place covered, ventilated and lighted			
2	Dining table and hall is free from flies and insects			
3	Surrounding are clean and free from flies and insects			
4	Daily use of disinfectant for cleaning of surrounding			
5	No garbage near the restaurant			
6	No pets and street dogs near restaurant			
7	No animal/human disposal near restaurant			
8	Disposal of garbage in waste bins having proper lids			

3. Knowledge of cooks on food hygiene, nutrition and health and personal hygiene

Keys: **0: Wrong answer: 1: one correct answer; 2: two correct answers; 3: three correct answers; 4: all correct answers**

Sr. no	Questions	Response
	Food Hygiene	
1.	Name any four food borne illnesses	
a.		
b.		
c.		
d.		
	(Cholera, jaundice/hepatitis, typhoid, gastroenteritis, diarrhea, amoebiasis and any other)	
2.	Name four characteristics of spoiled food	
a.		
b.		
c.		
d.		
	(Discolouration of food, foul smell, deformity in texture, sour taste, gas formation, bubbling and any other)	
3.	Name four immediate symptoms of food borne illnesses	
a.		
b.		
c.		
d.		
	(Nausea & vomiting, heart burn, giddiness, diarrhea, stomach pain, loss of appetite, high fever and any other)	
4.	Name four ways to prevent bacterial contamination while handling food	
a.		
b.		
c.		
d.		
	(Buying fresh, avoiding cross contamination while cooking and serving, storing in safe environment, proper cleaning and sanitizing of equipment and surface area, proper management of drinking water, holding left over food out of danger zone and any other)	

5.	Name four food contaminants which make a food unsafe and unfit for consumption	
a.		
b.		
c.		
d.		
	(Dust, dirty hands, dirty mops, insects, bacteria, dirty water and any other)	
6.	Name four biological sources of food contamination	
a.		
b.		
c.		
d.		
	(Bacteria, insects, germs, amoeba, flies, fungus and any other)	
7.	Name four ways to manage left over food	
a.		
b.		
c.		
d.		
	(Do not hold for more than 2 hrs. at room temperature; DO not serve spoiled food; Storage at low temperature; Avoid mixing of left over food with fresh food; Reheat thoroughly and then serve and any other)	
8.	Name four ways of serving safe drinking water	
a.		
b.		
c.		
d.		
	(Always use clean vessels for holding and drinking; Raw water should not be added in cooked food; Use water purifier; Do not dip fingers in water; Serve water preferably in disposables; Use running tap water for drinking purposes and any other)	
9	Give four reasons to store raw material at dry place	
a.		
b.		
c.		
d.		
	(to protect from insects, to protect from spoilage, to keep them safe, to prevent from insects and micro organisms, to increase their shelf life, it is safe to keep at dry place, any other)	
10.	Give four reasons to cover cooked food after cooking	
a.		
b.		
c.		
d.		
	(to prevent from flies, to prevent from dirt, to prevent micro organisms to fall in food present in air, prevent from mixing to other food, to prevent the smell of food and anyother)	
	Nutrition and Health	
11.	Name four energy foods	
a.		
b.		
c.		
d.		

	(Cereals and cereal products, fats and oils, sugar, roots and tubers and any other)	
12.	Name four ways to conserve nutrients while processing and cooking food	
a.		
b.		
c.		
d.		
	(Washing before cutting and soaking, minimum peeling, use of just enough water for cooking, cooking at reduced temperature, use of pressure cooker and any other)	
13.	Name four nutrients which are essential for growth and maintenance	
a.		
b.		
c.		
d.		
	(Carbohydrate, protein, fat, mineral, vitamins and any other)	
14.	Name four food sources of protein	
a.		
b.		
c.		
d.		
	(Pulses and legumes, meat, fish, egg, milk and any other)	
15.	Name four rich sources of vitamins	
a.		
b.		
c.		
d.		
	(Orange and yellow fruits, green leafy vegetables, egg, butter, aonla, guava and any other)	
16.	Name any four food adulterants	
a.		
b.		
c.		
d.		
	(Water, liquid urea with detergent, starch, sawdust, artificial colour, marble powder, sand, metanil yellow and any other)	
17.	Name four common sources and minerals	
a.		
b.		
c.		
d.		
	(Food grain, green leafy vegetables, iodized salt, banana, fish, meat and any other)	
18.	Name four ways for value addition of the food products	
a.		
b.		
c.		
d.		
19.	List four harmful effects of excessive heating of oil	
a.		
b.		
c.		
d.		

	(Pungent fumes are evolved, generation of trans-fatty acids, enhanced cardio-vascular diseases, carcinogenic effect, indigestion; off-taste and bad odor in food product and any other)	
	Personal Hygiene	
20.	Name four protective clothes necessary for a food handler	
a.		
b.		
c.		
d.		
	(Hair restraints, apron, gloves, napkin, wrist cover and any other)	
21.	Name four bad habits which should be prohibited by food handlers	
a.		
b.		
c.		
d.		
	(Gutka eating/tobacco chewing, smoking, food tasting, scratching of body part, sweat/nose wiping and any other)	
22.	Name four activities which may contaminate food with harmful germs / bacteria	
a.		
b.		
c.		
d.		
	(Sneezing, coughing, vomiting, spitting, touching food with bare hands, wounds in your hand, nose wiping, sweat wiping and any other)	
23.	Name four activities after which hand wash with soap is a must	
a.		
b.		
c.		
d.		
	(Using the toilet, handling raw food, mopping, handling waste, changing soiled clothes, blowing nose and any other)	

<u>Information on oil</u>

4. Procurement and storage practice of oil

a) Oil used for frying

i) Cottonseed oil **[ ]** ii) Groundnut oil **[ ]**
iii) Palmolein oil **[ ]** iv) Any other, Specify _______

b) From where you buy the oil

i) Wholesale shop **[ ]** ii) Retail shop **[ ]**
iii) Contract basis **[ ]** iv) Any other, Specify __________

c) Purchasing practice

i) Loose oil **[ ]** ii) Tins **[ ]**
iii) Jerry cans **[ ]** iv) Any other, Specify __________

d) Reasons for not purchasing loose oil
i) Due to adulteration [ ] ii) Due to rancidity [ ]
iii) Due to presence of impurities[ ] iv) Any other, Specify __________

e)Have you ever noticed expiry date of oil?
i) Yes [ ] ii) No [ ]

f) If yes, what was it?
i) 6 months [ ] ii) 12 months [ ]
iii) 24 months [ ] iv) More than 24 months [ ]

g) Amount of oil purchased at a time __________________

h) Do you store fresh oil?
i) Yes [ ] ii) No [ ]

i) How long do you store purchased oil?
i) 1 month [ ] ii) 2 months [ ]
iii) 3 months [ ] iv) 6 months [ ]

j) Where do you store purchased oil?
i) Dark room [ ] ii) Open place [ ]
iii) Inside the cupboard [ ] iv) Any other specify [ ]

5. Frying practice
a) Have you ever measured frying temperature
i) Yes [ ] ii) No [ ]

b) Are you aware of correct frying temperature?
i) Yes [ ] ii) No [ ]

c) If yes, what is the correct frying temperature?
i) 100^0C [ ] ii) 160^0C [ ]
iii) 180^0C [ ] iv) 250^0C [ ]

d) Do you know how frying temperature is measured?

e) What type of frying vessel is used for frying?
i) Iron [ ] ii) Stainless steel [ ]
iii) Hindalium [ ]

f) How often you clean you frying vessel?
i) Daily [ ] ii) 2-3 times a week [ ]
iii) Once a week [ ] iv) After a week, specify__________

g) Do you know how frying vessel should be cleaned?
i) Yes [ ] ii) No [ ]

h) If yes, how?
i) with water only [ ] ii) with water and dish cleaning soap [ ]
iii) with water and caustic [ ] iv) Any other specify _____________

i) Do you know change in color is an indicator of deterioration of oil quality?
i) Yes [ ] ii) No [ ]

j) Do you know foaming in is an indicator of deterioration of oil quality?
i) Yes [ ] ii) No [ ]

k) Do you know change in consistency is an indicator of deterioration of oil quality?
i) Yes [ ] ii) No [ ]

l) Is the presence of food particles in fried oil is an indicator of deterioration of oil quality?
i) Yes [ ] ii) No [ ]

m) What do you do with food particles in oil?
i) separate them from oil before frying every time [ ]
ii) do not separate them from oil and fry in same oil [ ]

n) Do you add fresh oil in fried oil?
i) Yes [ ] ii) No [ ]

o) One batch of oil should be continuously or intermittently fried for how many hours?
i) 2 h [ ] ii) 4 h [ ] iii) 8 h [ ] iv) More [ ]

6. Storage of fried oil

a) Do you store leftover fried oil?
i) Yes [ ] ii) No [ ]

b) If yes, in which utensil
i) Same pan in which the food was fried [ ]
ii) Plastic container [ ]
iii) Stainless steel jar [ ]
iv) Other utensil [ ]

c) Practice of storing fried oil
i) Filtered [ ] ii) Without filter [ ]

CHAPTER 10

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CHAPTER 9

RESEARCH PUBLICATIONS

Paper publications

- Ashima Gupta, Mini Sheth 2011. Suitability of groundnut oil for repeated deep frying. *J Lipid Sci Technol.* 43(3): 111-117.
- Ashima Gupta and Mini Sheth. Fried foods associated health risks in Gujarati housewives. *Nutr Food Sci*. In press
- Ashima Gupta and Mini Sheth. Cottonseed and Groundnut oil frying stability and sensory qualities of french fries. *Int Food Res J* (In communication).

Presentation in conferences

- **Oral presentation** on "Thermal degradation of intermittently deep fried cottonseed and groundnut oil and resultant sensory qualities of French fries", 65th Annual Convention, International Seminar & Expo on Oils, Fats & Oleochemicals: Food Security, Green Energy, & Environment, held on 3 – 5 December 2010, Delhi.
- **Oral presentation** "Safety of repeatedly heated groundnut oil in terms of chemical and physical properties", National Seminar on "Consumer Protection and Food Safety" held on 8 - 9 October 2010, Baroda.
- **Poster presentation** on "Intermittent frying stability of cottonseed oil and sensory quality of bhajia fried in it" in ICFOST conference held in 2012, Pune.
- **Poster presentation** on "A case study on-prevailing food safety practices in JAN AAHAR- A government run food outlet at Vadodara railway station" in Gujarat Science Congress held in 2012, Vadodara.

CHAPTER 8

FUTURE SCOPE OF INVESTIGSTION

- Chemical stability and sensory quality other than GNO and CSO used for frying purpose can be further studied for different types of Indian fried foods.
- More advanced parameters such as polymer content, dielectric constant, oxidized glyceride content etc. can be studied for assessing the quality of repeatedly heated oils.
- Effect of education on good frying practices to the vendors preparing fried foods, may reduce the possibilities of using deteriorated oil.
- Assessment of sensory quality and stability of fried oils from organized and non-organized food sector can be studied.

CHAPTER 7

IMPLICATIONS OF STUDY

Results of the present study showed that chemical quality of both cottonseed oil (CSO) and groundnut oil (GNO) decreased significantly at the end of 25 h of intermittent frying. Sensory quality of french fries and bhajias fried in CSO and GNO were acceptable up to 21 h of intermittent frying.

Study has shown that frequent intake of fried and shallow foods in diet may responsible for high prevalence of obesity among the studied Gujarati housewives. Daily consumption of shallow fried foods on daily basis showed association with prevalence of diabetes. Use of *vanaspati* for food preparation showed significant association with prevalence of hypertension. Results also revealed that Gujarati housewives had poor knowledge on oils blends and *trans* fats.

The major implications of the study are as follows:

- 15 h of intermittent frying although did not alter the sensory qualities of both french fries and bhajias fried in CSO and GNO. An increase in saturated fats to polyunsaturated fats ratio was seen in both the oils. Along with this significant increase in ratio, the oxidized products were also increased with the duration of frying. Both these effects were more prominent in fried CSO as compared to fried GNO. Hence the study implies that food products should not fried for more than 15 h of intermittent frying for maintaining a safe limit of degraded products in the oils.

- The study implies that frequent consumption of fried foods have shown to be positively associated with incidences of obesity and significant association was also seen with frequency of consumption of shallow fried foods with diabetes. Hence the study implies that the popular practice of shallow fried food consumption by the Gujarati housewives should be reduced so as to limit the rising rate of obesity and diabetes in Gujarati population.

- The survey clearly showed a strong association between consumption of *vanaspati* and hypertension indicating a need for educating the Gujarati population regarding the harmful effects of *vanaspati* rich foods (40%), ready-to-eat foods such as *nankhatai*, *khari* biscuits and other biscuits and *farsaan*.

CHAPTER 6

SUMMARY AND CONCLUSION

Fats and oils are recognized as essential nutrients in human diets and are the most concentrated source of energy. Vegetable oils and fats are principal sources of fat in the diet. However, excessive consumption of fats in diet, derived from plant sources, elevates LDL cholesterol, which is one of the culprits responsible for cardiovascular diseases. Therefore there has been a resurgence of interest in the role that fats play in health and disease. Deep fat frying is an important, common and highly versatile process, for which oils and fats has been used from antiquity to cook a wide variety of products. Repeated frying results in changes in chemical and physical properties of oil, thus reduce the quality of oil. Consumption of such oils has been documented to adversely affect the health of individuals in many ways. Thus the present study was undertaken to assess the edible oil and fried food intake and its association with prevalence of NCDs in Gujarati housewives of urban Vadodara. The thermal stability of two popular edible oils (Cottonseed and Groundnut oil) used for frying french fries and bhajias was also studied in terms of their fatty acid profile, total polar components, peroxide value, p-anisidine value, acid value, iodine value, refractive index and color. The sensory quality of french fries and bhajias fried in these oils intermittently, was studied with respect to various organoleptic attributes and finally the frying practices and other food safety practices of a railway food outlet was determined. IEC material for safe frying practice was also developed. The results of the study are summarized and concluded as follows:

6.1 PHASE I

Consumption of edible oil in Gujarati diet is considered very high as compared to other states of India. This phase was designed to study the practices on type of oil used for cooking. The survey was specifically aimed at collecting information from Gujarati housewives on the consumption pattern of popularly consumed deep fried and shallow fried foods and deep fried sweets prepared at home and purchased from market. Consumption of these foods was correlated with prevalence of NCDs. The association between the knowledge level on *trans* fats and the education level of the subjects was also determined.

6.1.1 Salient features of Phase I

- Most of the subjects belong to middle income group and about 57.5% housewives were graduate.
- Deep fried products prepared at home were consumed by 5% of households on daily basis and 55% and 60% households consumed fried foods on a weekly and fortnightly basis.
- Shallow fried foods were consumed by 43% of households on daily basis and 49% and 44% consumed shallow fried foods weekly and fortnightly basis. None of the households consumed deep fried sweets on daily basis. Most of the surveyed subjects were vegetarian and resorted to roasting as most popular cooking method.
- 58.8% of Gujarati housewives were obese and 25.2% were overweight. Other co-morbidities related to obesity such as hypertension and diabetes were present in 16% and 8% housewives respectively. Significant association was seen between diabetes and obesity.
- Consumption of homemade shallow fried foods significantly correlated with prevalence of diabetes.
- Fried food purchased from market fortnightly and its consumption showed a significant association with prevalence of GI problems.
- Eating out in restaurants/ parties on a weekly basis was preferred by 22% Gujarati housewives and 7% never preferred eating out. However, no association was found between prevalence of NCDs, GI problems and eating out frequency.

- Many families reported daily use of saturated fats such as *vanaspati* (26%), ghee (100%) and butter (76%). Use of *vanaspati* showed a significant association ($p<0.001$) with prevalence of hypertension. However, consumption of butter did not show association with prevalence of NCDs and GI problems.
- Awareness on recommended daily intake of vegetable oils was reviewed, 58.8% do not know about the daily intake allowances of oil.
- Knowledge on *trans* fats was assessed and it was found that only 34.8% know about the *trans* fats, and 31.2% know the sources of trans fat.
- Only 15.6 % house wives answered correctly that oil blends are the combination of different oils and only 25.2 % of house wives were aware of oil blends.

From the results of phase I, it can be concluded that saturated fats and ready-to-eat foods are consumed on daily basis which may be a significant contributor of high prevalence of obesity and other co-morbidities. Most subjects did not have knowledge on recommended daily intake of oils, oil blends and *trans* fats. Hence education on correct amount of oil intake, oil blends and *trans* fats is suggested to reduce prevalence of NCDs.

6.2 PHASE II

This phase was aimed to assess the sensory quality of french fries and bhajias intermittently fried (0, 6, 11, 16 and 21 h) in cottonseed oil (CSO) and groundnut oil (GNO).

6.2.1 Salient Features of Phase II

6.2.1.1 Sensory quality of french fries intermittently fried in CSO and GNO

- Appearance, color, crispness, greasiness and taste of french fries fried intermittently in CSO and GNO showed no significant change.
- Significant reduction ($p<0.05$) in flavor, odor and overall acceptability scores was noticed as the duration of frying in GNO increased from 6-

21 h, whereas these scores reduced significantly ($p<0.05$) for CSO from 16-21 h.

- With regards to taste, odor and overall acceptability GNO fried french fries were significantly ($p<0.05$) more acceptable as compared to CSO fried fries at initial hours of frying.
- Oil uptake during intermittent frying of french fries was 12% in GNO and 11.5% in CSO.

6.2.1.2 Sensory quality of bhajias intermittently fried in CSO and GNO

- As the duration of frying increased from 0-21 h a non significant change was observed in all sensory qualities of bhajias.
- The crispness scores of bhajias improved as the duration of frying increased although this increase was not statistically significant.
- During intermittent bhajias frying oil uptake was higher in GNO (19.65%) as compared to CSO (15.6%).

To conclude, the sensory qualities of CSO prepared french fries does alter when fried intermittently in repeatedly heated oil. Overall acceptability of french fries fried in GNO was more than CSO prepared fries. Bhajias showed no change in the sensory qualities up to 21 h of intermittent frying. However, both french fries and bhajias were acceptable as per the hedonic rating scale.

6.3 PHASE III

6.3.1 Salient Features of Phase III

In this phase of the study thermal stability of refined and double filtered CSO and GNO respectively was studied by intermittent frying of french fries and bhajias up to 25 h with respect to fatty acid profile, total polar components, peroxide value, p-anisidine value, acid value, iodine value, refractive index and color.

6.3.1.1 Chemical changes in CSO and GNO used for intermittent frying of french fries

- Intermittent frying of french fries in CSO and GNO results significant ($p<0.05$) change in chemical properties of both the oils.
- The peroxide value, p-anisidine value and totox value increased significantly ($p<0.001$) when french fries were fried intermittently up to 25 h. Though CSO showed significantly lower ($p<0.001$) stability than GNO.
- Positive correlation was found between peroxide value and p-anisidine value of both the oils with duration of frying.
- Iodine value, indicator of unsaturation in oil showed a significant decrease ($p<0.01$) in CSO (14.45%) and GNO (17.64%) as the frying duration of french fries increased.
- Significant increase ($p<0.01$) in acid value and total polar components (indicator of hydrolysis) was observed when french fries were fried intermittently up to 25 h.
- Intermittent french fries frying in CSO and GNO up to 25 h showed a significant change in fatty acid profile of both the oils. Palmitic acid (saturated fatty acid) increased by 16.4% and 11.8% in CSO and GNO respectively.
- Monounsaturated fatty acid/monoene i.e. oleic acid increased by 4.4% in GNO and 9.2% in CSO when french fried were intermittently fried up to 25 h.
- Linoleic acid decreased by 12.7% in CSO and 26% in GNO. The other polyunsaturated fatty acid i.e. linolenic acid was totally missing after 15 h intermittent frying of french fries in GNO.
- Significant decrease ($p<0.01$) in linoleic/palmitic ratio was seen in CSO (25%) and GNO (33.8%).

6.3.1.2 Changes in physical parameters of CSO and GNO used for intermittent frying of french fries

- Color and refractive index of CSO and GNO increased significantly ($p<0.001$) with the increase in frying duration.

6.3.1.3 Chemical changes in CSO and GNO used for intermittent frying of bhajias

- Bhajias frying result in significant increase ($p<0.001$) in peroxide value, p-anisidine value and totox value of CSO and GNO during the intermittent frying of 25 h. CSO showed lesser oxidative stability than GNO and no correlation was found between peroxide value and duration of frying.
- Significant decrease ($p<0.05$) in iodine value of bhajias fried CSO was observed. However, iodine value of GNO was not altered during 25 h of intermittent frying.
- Strong correlation (GNO $r^2=0.98$ and CSO $r^2=0.93$) and significant increase ($p<0.001$) in acid value of bhajias fried CSO and GNO was seen.
- At 25 h of intermittent frying total polar components of CSO and GNO was increased from 4 to 14.3 and 3.12 to 7.58 respectively.
- The saturated fatty acid content (palmitic and stearic acid) of GNO increased significantly ($p<0.05$) with the increase in frying hours. Stearic acid of CSO did not alter significantly.
- Oleic acid of CSO and GNO increased significantly ($p<0.05$) at 15 h of intermittent frying.
- The linolenic fatty acid of CSO was not significantly changed while the linolenic fatty acid of GNO was not detected at 15 and 25 h of intermittent frying.
- The linoleic acid to palmitic acid ratio (18:2/16:0) decreased significantly ($p<0.01$) in CSO whereas GNO 18:2/16:0 ratio showed no significant reduction during 25 h intermittent frying.

6.3.1.4 Changes in physical parameters of CSO and GNO used for intermittent frying of bhajias

- Refractive index and color of bhajias fried oils increased as frying duration increased.

Present phase concludes that frying of french fries and bhajias bring considerable thermal-oxidation of CSO and GNO at 5 h of intermittent frying and continued up to 25 h of intermittent frying as indicated by rise in chemical and physical properties of oil. Decrease in 18:2/16:0 ratio was greater in CSO than GNO when french fries and bhajias were intermittently fried for 25 h. Hence, it can be concluded that CSO is less stable than GNO when used for intermittent frying for 25 h.

6.4 PHASE IV

6.4.1 Salient Features of Phase IV

Safe food is one of the three essentials for maintenance of life and health. Therefore, present phase was designed to determine the current food safety practices prevailing at the Government run food outlet Jan aahar at Vadodara railway station particularly with respect of use of oils.

6.4.1.1 Case study on prevailing food safety and frying practices in Jan aahar- a government run food outlet at Vadodara railway station

- Jan aahar, a catering outlet is situated at western zone railway station- Baroda. Of the total of 10 kitchen staff members only 4 members had under gone the food safety training program.
- Food hygiene knowledge scores of Jan aahar kitchen staff was 75% and it ranged from good to excellent. Supervisor, manager and head cook scored maximum for food hygiene. However, correct way to manage leftover food was known by only 52% of kitchen staff.
- Knowledge scores on nutrition and health of kitchen staff ranged from poor to good (40.78%). Waiters and assistant cook obtained lowest

scores 22-27% (poor) on nutrition and health respectively as compared to other staff with manager scoring the highest (69%).

- The personal hygiene knowledge scores for the kitchen staff ranged from 50% for a cleaner to 100% for most staff.
- Infrastructural facilities like clean cloth, moping cloth for tables, counters, geyser for washing utensils, separate store for raw materials etc. were lacking.
- Both the cooks did not know about the correct frying temperature. Although cooks had good knowledge about the deterioration of oil quality during frying. Also the cooks followed the practice of discarding the oil for frying purpose at the end of day and used fresh batch of oil each day.

Hence this phase concludes that the food hygiene and personal hygiene practice scores of Jan aahar was good to excellent. However, the infrastructure facilities were lacking. Their frying practices were also found to be good. Food safety training can further improve the knowledge level of the staff and further enhance the good manufacturing practices (GMP).

PHASE V

5.1: DEVELOPMENT OF NUTRITION HEALTH EDUCATION (NHE) MATERIAL IN TWO LANGUAGES ON INTAKE OF EDIBLE OIL, TYPES, AND ON CHOICES OF OILS FOR HEALTHY LIVING AND PROBLEMS DURING FRYING OF EDIBLE OIL AND ITS STORAGE.

"Health education or communication (HE/C), i.e., interpersonal or mass communication activities focused on improving the health of individuals and populations" (Nutbeam D, 1998) has emerged as a positive way to educate people on important health issues. Review article by Ishikawa H and Kiuchi T (2010) stated that according to US Healthy People 2010 project, dissemination of individual and population health risk information is under the risk communication and construction of public health messages may contribute to disease prevention and health promotion.

In present phase of the study NHE was developed to educate people about edible oil recommended intake, sources, storage, correct practices of frying and calorie content of common fried foods.

This phase was divided under the following heads:

5.5.1: To develop IEC material on edible oil, types of oil, and its composition.

5.5.2: To develop IEC material on frying and problems during frying.

5.5.1: To develop IEC material on edible oil, types of oil and its composition.

"KNOW YOUR FATS AND OILS" IEC material was developed in two languages (Hindi and English) shown in Figure 5.5.1.

5.5.2: To develop IEC material on frying and problems during frying.

Figure 5.5.2 shows education material on frying, safety of fried foods, common problems envisaged during frying and calorie content of common fried foods.

Figure 5.5.1: Brochure on oils and fats in English and Hindi

Causes of smoking and its solutions

Causes	Corrections
Insufficient turnover of oil	Maintain minimum quantity of oil in fryer for more rapid turnover or increase quantity of food fried in fryer.
Continual frying with excess moisture on food	Drain foods before frying
Contamination of oil	Strain daily to remove contaminants. Filter weekly.
Poor cleaning practice	Clean fryer thoroughly at least once a week or each day in cases of heavy usage. Ensure fryer is perfectly dry before use.
Overheating of oil	Check temperature with a thermometer.
Use of unrefined oils	Use refined and deodorized oils.

Calories and fat content of some common non vegetarian fried foods

Food	Serving	Calories	Fat (g)
Fried chicken	One	443	35
Fried egg	One	175	16.6
Fried prawns	1 mk (medium katori)	269	21
Fried fish	1 mk	363	30
Egg fried rice	1 plate	337	16.7

Calories and fat content of some common vegetarian fried foods

Food	Serving	Calories	Fat (g)
Puris (small)	Four	192	10.5
Parantha	One	243	10.7
Bhatura	One	235	15.5
Potato chips/aloo tikkis/ papad (fried)	12pcs/ two/ one	187/194 / 142	10.1
Mathri/Sev	Two/ 30g	159/200	10.5
Veg frankie	One	285	13
Onion bhajia/potato bhajia/ragda pattice/spring rolls	Eight /eight/ 1 plate/ four	300/370 /450/35 5	16
Sabudana vada	Two	352	14.1
Medu-vada/veg pattice/veg cutlets	Two	260/350 /320	15
French fries	1 bk (big katori)	280	15.1
Khasta kachori/ veg burger	1 plate/ 1	245/438	18.7
Pav bhaji/sev puri/punjabi samosa	1 plate/ two	600/400 /312	20
Paneer pakoda/shakarpara	Six / 1 bk	500/450	25

Source: The saffola food check (calorie content of over 1000 food items)- Dr. Rajesh Parekh

SAFETY OF FRIED FOODS

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WHAT IS FRYING?

Frying is a fast cooking method, which requires little or no preparation of the food save for the provision of a uniform portion, application of a batter and addition to hot oil.

Many complex reactions occur during the frying process:

•Oxidation - Caused by the reaction of oxygen with the hot oil.

•Polymerization - A catalytically driven reaction of the oil and its degradation products to produce large molecules of polymeric proportions.

•Hydrolysis - Reaction of water or other components containing an OH group

What are good frying practices?

•Frying should be done at 160-180°C. Avoid overheating of oil.
•Immerse the food in the oil after it has reached a temperature of about 180°C.
•During frying fryer should not be overloaded with the product.
•Oils that can sustain high temperature should be used for frying.
•Use oil not more than two or three times and filter it after 2-3 frying.
•Break-up the food to be fried into small pieces to obtain a quick formation of surface crust.
•Before frying excess water should be removed from the product.
•Remove excess oil immediately after frying.
•Fresh oil should not be topped in used/fried oil
• Right size of frying vessel should be of used.
•For batch frying excess amount of oil should not be used. Fresh oil can be loaded in the fryer once previous oil is used.

Frying problems and their solutions

Causes of foaming and its solutions

Causes	Corrections
Presence of soap or detergent residue from cleaning	Clear all debris from the fryer and rinse with small aliquots of fresh hot oil. Fryer should be perfectly dry before re-filling with oil
Excessive breakdown of oil	Filter oil frequently and use regular top ups.
Continual frying of food with excess moisture	Remove excess moisture from foods to be fried
Continued overheating of oil	Turn down heat about 121°C when frying is not performed.
Overloading fryer	Maintain 1-6 ratio of food to oil

Causes of greasiness and its solutions

Causes	Corrections
Frying at low temperatures	Increase temperature up to 180°C during frying
Excessive quantities of breading or batter	Remove surplus breading or batter
Surplus moisture in and on surface of foods	Drain and dry foods before frying
Frying oil in advanced stages of breakdown	Discard deteriorated oil .This oil will not serve as an adequate heat transfer medium
Using the wrong kind of cooking oil	Always use refined and deodorized cooking oil for frying.

Causes of rapid oil breakdown and its solutions

Causes	Corrections
Inadequate frying oil turnover	Adjust procedures to fry more food in fryer to increase turnover of oil
Overheating of oil	Check temperature frequently
Contamination	Filter oil regularly
Poor cleaning procedures	Clean fryer each day or at least once a week. Dry fryer before use
Presence of copper or brass in fryer	Remove all copper or brass fittings from contact with oil
Overloading fryer	Maintain 1:6 ratio of food to frying oil
Excessive moisture on food	Drain and dry foods before frying
Overheating of oil on standby	Reduce temperature of frying oil to 93°-121°C
Stack 'drip back'	Keep oil clean

Causes of darkening of oil and its solutions

Causes	Corrections
Presence of salt on food	Salt foods AFTER frying and away from fryer
Oil contamination	Filter oil daily
Poor cleaning practice	Clean fryer thoroughly once a week or each day in cases of heavy usage.
Overheating of oil	Check temperature with the help of thermometer
Insufficient oil turnover	Top up daily to replace contents of fryer.

तलने वाले तेल का काला होने के कारण एवं उसकी रोकथाम के उपाय

कारण	उपाय
आहार में नमक होना	तलने के बाद तवे से दूर करके आहार में नमक डालिये।
तेल दूषित होना	तेल को नियमित रुप से फिल्टर कीजिये ।
अपूर्ण सफाई	तवे को कम से कम हफ्ते में एक बार और अगर ज्यादा इस्तेमाल होता हो तो रोज पूर्ण रूप से साफ कीजिये । इस्तेमाल करने के पहले तवा बिल्कुल साफ एवम् सूखा हुआ निश्चित कीजिये ।
तेल ज्यादा गरम होना	थर्मोमीटर के जरिये तापमान की जांच करें ।
तेल से अपर्याप्त मात्रा में खाना तैयार होना।	तलने वाले तेल को नियमित रूप से बदले ।

तलने वाले तेल से धुँआ निकलने के कारण एवं उसकी रोकथाम के उपाय

कारण	उपाय
तेल प्रदूषित होना	नियमित रुप से तेल को फिल्टर कीजिये और प्रदूषकों को दूर किजिये । हफ्ते में एक बार फिल्टर कीजिये ।
अपूर्ण सफाई	तवे को कम से कम हफ्ते में एक बार और अगर ज्यादा इस्तेमाल हो तो प्रतिदिन पूर्ण रूप से साफ कीजिये । तवे का उपयोग करने से पहले निश्चित कर लीजिये की वह पूर्ण रूप से सूखा हुआ है।
तेल ज्यादा गरम हो जाना ।	थर्मोमीटर के जरिये थर्मोस्टेट सेटिंग्स की जांच कीजिये ।
अपरिशुद्ध (Unrefined) तेलों का उपयोग ।	Refined तेल का प्रयोग करें ।

तले हुए मांसाहारी खाद्य पदार्थों में केलोरी और फेट की मात्रा

नाम	मात्रा	केलोरी	फेट (g)
फ्राइड चिकन	१	443	35
फ्राइड एग	१	175	16.6
फ्राइड प्रॉन्स	१ मध्यम कटोरी	269	21
फ्राइड फिश	१ मध्यम कटोरी	363	30
एग फ्राइड राइस	१ प्लेट	337	16.7

तले हुए शाकाहारी खाद्य पदार्थों में केलोरी और फेट की मात्रा

नाम	मात्रा	केलोरी	फेट (g)
पुरी (छोटी)	४	192	10.5
पराठा	१	243	10.7
भटुरा	१	235	15.5
आलु चिप्स/आलू टिक्की/ पापड (फ्राइड)	१२ नग/ दो/एक	187/194 / 142	10.1
मठरी/सेव	दो/३० ग्राम	159/200	10.5
वेज. फ्रेन्की	१	285	13
ओनियन भजिया/आलू भजिया/रगडा पेटिस/ स्प्रिंग रोल्स	आठ/आठ/१ प्लेट/चार	300/370 /450/35 5	16
साबुदाना वडा	दो	352	14.1
मेदु-वडा/वेज पेटीस/ कटलेस	दो	260/350 /320	15
फ्रेंच फ्राइस	१ बडी कटोरी	280	15.1
खस्ता कचौरी/ वेज बर्गर	१ प्लेट/१	245/438	18.7
पाव भाजी/सेव पुरी/ पंजाबी समोसा	१ प्लेट/दो	600/400 /312	20
पनीर पकोडा/ शक्करपारा	छह/ १ बडी कटोरी	500/450	25

Source: The saffola food check (calorie content of over 1000 food items)- Dr. Rajesh Parekh

तले हुए खाद्य पदार्थ की सुरक्षा के तरीके

आशिमा गुप्ता   डॉ. मिनी शेठ

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तलना क्या होता है?

तलना एक भोजन पकाने की विधी है, जिसमें भोजन तैयार करने के लिये गरम तेल के अतिरिक्त अच्छे तेल की भी जरुरत होती है। खाना तलते समय तेल में निम्न तीन बदलाव आते है :-

ऑक्सिडेशन : ऑक्सिडेशन ऑक्सिजन की गरम तेल के साथ प्रतिक्रिया के फल स्वरुप होता है एवम् सकारात्मक रुप से उत्तेजित खाद्य कणों की ट्रायग्लिसराईड्स के टूटने की प्रक्रिया के फल स्वरुप होता है।

पॉलिमराजेशन – यह तलने के कारण होने वाली प्रक्रिया है इसमें तेल का विघटन होता है तथा बडे कण बनते है।

हाइड्रोलाइसिस – यह पानी या OH ग्रुप वाले घटकों की प्रक्रिया है। हाइड्रोलाइसिस की प्रक्रिया आल्कलाईन या ऐसिडिक दोनो तरह की हो सकती है।

तलने की अच्छी प्रक्रियाएँ :

- तलने की प्रक्रिया १६०-१८० डिग्री होनी चाहिये । ज्यादा गरम न करें तेल ।
- १८० डिग्री होने पर ही खाना तलने के लिये तेल में डालें ।
- एक साथ बहुत सारा खाना न तलें ।
- तलने के लिये वही तेल उपयोग मे ले तो ऊँचे तापमान पर ही जल्दी खराब न हो ।
- दो-तीन बार से ज्यादा तेल में न तलें । तलने के बाद तेल को फिल्टर जरूर करें ।
- खाने को छोटे-छोटे भागो मे बाँट कर तलें जिससे खाना जल्दी पकेगा ।
- खाने को तलने से पहले पानी को सुखा लें ।
- तलने के बाद खाने पर अधिक लगा हुआ तेल टिस्यु पेपर से हटा ले ।
- तलने के लिये उचित माप के बर्तन का प्रयोग करें ।
- एक साथ बहुत सारा तेल न लें । कुछ बार तलने के बाद फिर से नया तेल ले ।
- तलने के उपयोग किये हुए तेल में नया तेल न डालें ।

तेल में तलने की समस्याओं का मार्गदर्शन

तले हुये तेल में फेन (झाग) बनने के कारण और उसे दूर करने के उपाय

कारण	उपाय
सफाई के बाद साबून या डिटरजन्ट के अवशेष रह जाने के कारण	तवे में डाला पूरा तेल खाली कर दीजिये और सम भाग ताजा गरम तेल के साथ तवे को गरम करे। तवे में फिर से तेलभरने के पहले देख लीजिये कि तवा बिलकुल सूखा है।
ज्यादा तेल जलना	हर हफ्ते तेल को फिल्टर कीजिये और हमेशा ढक्कन का इस्तेमाल कीजिये। अगर ज्यादा तेल का इस्तेमाल हुआ है तो उसकी जगह नया तेल डालिये
ज्यादा पानी युक्त आहार को देर तक तलते रेहना ।	जिस खाद्य चीज को तलना हो उसमें से अतिरिक्त पानी दूर कीजिये।
तेल में बार-बार तलने के कारण ज्यादा गरम हो जाता है।	थर्मोस्टेट चेक कीजिये। तापमान 121°C (250°F) तक पहुँचने के बाद चूल्हा बंद कर दीजिये।
तवे में ज्यादा खाद्य पदार्थ होना	आहार : तेल की मात्रा १:६ की रखिये

तेल चिपचिपा होने के कारण और उसे दूर करने के उपाय

कारण	उपाय
तेल बार-बार और जल्दी से गरम करना	शुरु करते समय तेल को आहिस्ता-आहिस्ता पिघलने दो।
तेल बार-बार ज्यादा गरम हो जाना	थर्मोमीटर के जरिये थर्मोस्टेट सेटिंग्स (उष्मा नियंत्रण व्यवस्था) की जांच कीजिये।
तलने के तेल का विघटन (खराब) हो जाना	तवे में डाले गये नये तेल की मात्रा उचित है कि नहीं उसकी जांच कीजिये।
गलत रसोई तेल का इस्तमाल करना	कुछ तेल जब तलने के लिये इस्तमाल किये जाते है, तब वे चिपचिपापन पैदा करते है। जैसे सूरजमूखी का तेल / कॉर्न ओईल।

तले हुये खाने में अधिक चिकनाई होने के कारण और उसके रोकथाम के उपाय

कारण	उपाय
कम तापमान पर तलना ।	तापमान बढाईये और थर्मोस्टेट की सेटिंग्स जांच कीजिये ।
अपूर्ण रुप से खाना तैयार होना ।	खाना (खास करके आलू इत्यादी) पूरी तरह पक गया है या नहीं उसकी जांच कर लीजिये ।
खाद्य पदार्थ की मात्रा ज्यादा होना ।	तलने के पहले अतिरिक्त खाद्य पदार्थ को निकाल दीजिये ।
खाने के अंदर और सतह पर ज्यादा नमी होना ।	खाना तलने के पहले पानी बहाकर उसे सुखा दीजिये । खाना तलने के पहले पानी बहाकर उसे सुखा दीजिये ।
तेल खराब होने के अंतिम चरण में होना ।	खराब तेल को निकाल दीजिये और तवे को फिर से गरम कीजिये । खराब हुआ तेल, पर्याप्त मात्रा मे ऊर्जा परिवहन के माध्यम के रूप में काम नहीं करेगा ।
डिपिंग या अन्य अपरिशुद्ध (unrefined) तेल का इस्तेमाल करना ।	उत्कलन बिंदु (Smoke Point) कम होने के कारण कम तापमान पर तेल को गरम करके तलने से खाना ज्यादा तेल सोखता है ।
गलत प्रकार के रसोई के तेल का इस्तेमाल करना ।	हमेशा पूर्ण रूप से परिशुद्ध (refined) किया गया रसोई तेल का ही इस्तेमाल कीजिये ।

तलने वाले तेल का जल्दी खराब होने के कारण एवं उसके रोकथाम के उपाय

कारण	उपाय
तलने के तेल से अपर्याप्त मात्रा मे खाना बनना ।	तेल से ज्यादा खाना तलने के लिये अनुरुप प्रक्रिया का पालन करे।
तेल ज्यादा गरम हो जाना ।	थर्मोमिटर से थर्मोस्टेट सेटिंग्स की जांच कीजिये ।
तेल का प्रदूषित होना ।	तेल को रोज, कम से कम हफ्ते में एक बार फिल्टर कीजिये ।
अपूर्ण सफाई या तेल ज्यादा गरम हो जाना।	तवे को रोज या कम से कम हफ्ते में एक बार साफ कीजिये । इस्तेमाल करने से पहले तवे को सुखा दीजिये ।
तलने के उपकरण मे तांबा या पीतल होना ।	तेल के सम्पर्क में आने वाले सभी तांबे या पीतल के फिटिंग्स दूर कर दीजिये ।
तवे को अत्यधिक भर देना ।	आहार के सामने तेल की मात्रा १:६ के प्रमाण में रखिये ।
आहार में ज्यादा नमी होना ।	आहार को तलने के पहले उसमें से पानी बहाकर उसे सुखा दीजिये ।
"टपकता हुआ तेल" एकत्रित हो जाना ।	आपकी जाली (जारी) साफ रखिये ।

Figure 5.5.2: Brochure on safety of fried foods in English and Hindi

PHASE IV

5.4: CASE STUDY ON PREVAILING FOOD SAFETY AND FRYING PRACTICES IN JAN AAHAR- A GOVERNMENT RUN FOOD OUTLET AT VADODARA RAILWAY STATION

The health and the nutritional status of the people, depends to a large extent on the quality of food they eat. It is therefore essential to ensure that the food they consume is safe and wholesome. Safe food may be defined as, "a product which contains no physical, chemical or microbiological organisms or by products if consumed by man will result in illness, injury or death-an unacceptable consumer health risk" (Stier 2000). FDA (2004) and MOH (2001) have outlined five risk factors that need to be evaluated and assessed in complying with safe food preparation. They are safe food sources, food storing temperature and stock control, personal hygiene practice, cross contamination and safe temperature of holding food.

Apart from the microbial safety of foods, chemical changes in food during processing needs to be looked upon for their nutritional safety. Agreements in the form of legislation must be put in place in order to ensure that safe and healthy food reaches consumers.

Thus, the IV phase of present study was designed to determine the current food safety and frying practices prevailing at the Government run food outlet Jan aahar at Vadodara railway station particularly with respect to use of oils.

The results of this phase are presented under the following heads:

5.4.1: General information and hierarchy of Jan aahar-a food joint at Vadodara railway station

5.4.2: General information of staff members working at Jan aahar

5.4.3: Knowledge on food hygiene, nutrition and health and personal hygiene of kitchen staff at Jan aahar

5.4.4: Observed practices of cooks, cleaners and waiters on personal hygiene

5.4.5: Observed practices on food hygiene, environmental hygiene and unit hygiene

5.4.6: Oil procurement and storage and frying practices

5.4.1: General information and hierarchy of Jan aahar- a food joint at Vadodara railway station

Jan aahar was established in May 2009 at western zone railway station-Baroda. Jan aahar is managed by railway staff. It was taken over from IRCTC (Indian Railway Catering and Tourism Corporation) in June 2011, due to mass complaints regarding quality of food and services. Railway ministry has decided to provide health foods to the passengers at cheaper rates approved by Indian railways. Jan aahar is currently running in loss at the rate of 2 laks 40 thousand per month.

All food handling staff has their medical fitness certificate from Railway doctor every year. Fixed amount of ration is provided by Railways to food outlet. Accounting of the sales is being checked by accounts department of railways on day to day basis. Raw materials are purchased from local market by purchasing committee assisted by 1 commercial officer, 1 accounts officer and 1 medical officer. Quality and rates of the purchased products is checked by the purchasing committee. Cleanliness of the premises is maintained by cleaners twice a day. Food preparation is carried out daily 3 times a day and approximately 250 customers make use of this outlet. The daily income is about Rs. 3500. Figure 5.4.1 shows the hierarchy of Jan aahar kitchen staff.

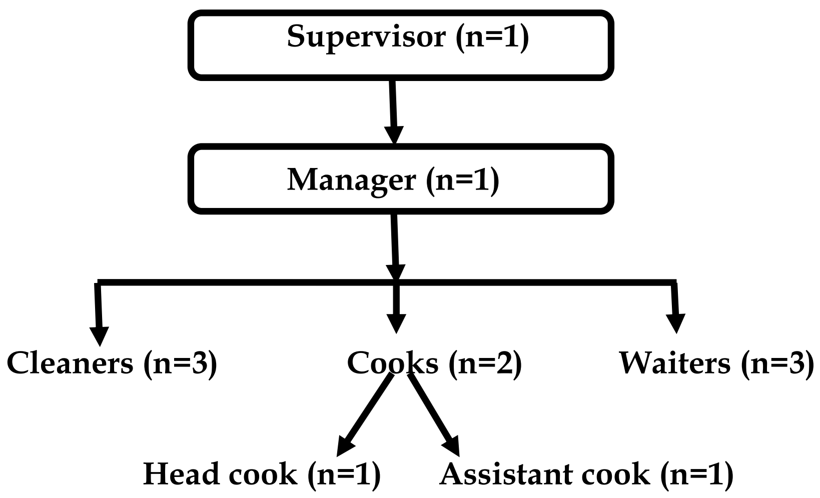


Figure 5.4.1: Hierarchy of Jan aahar kitchen staff

5.4.2: General information of staff members working at Jan aahar

Table 5.4.2 shows general information of the staff members working at Jan aahar. A total of 10 members are presently working in kitchen. It was found that manager was educated up to graduation. However, 2 staff members were found illiterate indicating 20% illiteracy. Out of 10 staff members only 4 staff members were trained in food safety. Majority of food handlers were in the age group of 31-45 year. All the kitchen staff at Jan aahar work for 8 hours in two shifts.

Table 5.4.2: General information of staff members working at Jan aahar

Work doing	Education	Age	Food safety training Yes/No
Supervisor	Graduate	58	Yes
Manager	Graduate	47	Yes
Head cook	Illiterate	57	Yes
Asst. cook	Primary	58	No
Cleaner 1	Primary	28	No
Cleaner 2	Primary	55	No
Cleaner 3	Primary	56	No
Waiter 1	Illiterate	60	No
Waiter 2	High school	50	No
Waiter 3	High school	50	Yes

5.4.3: Knowledge on food hygiene of kitchen staff at Jan aahar

The knowledge scores on food hygiene of kitchen staff working at Jan aahar at Vadodara Railway Station is shown in Table 5.4.3.1. F-test on food hygiene knowledge scores of all the kitchen staff showed no significant difference. However, supervisor gained maximum score (85%) on food hygiene knowledge amongst all the other kitchen staff. Cleaners and waiters showed 62-80% food hygiene knowledge. Amongst the various aspects of food hygiene knowledge, correct way to manage leftover food was fairly known (52%) by all the kitchen staff with excellent (90%) scores obtained for knowledge on characteristics of spoiled food.

Knowledge scores on nutrition and health of Jan aahar kitchen staff is shown in Table 5.4.3.2. A significant difference ($p<0.05$) was observed amongst the knowledge scores of kitchen staff. Waiters and assistant cook obtained lowest scores 22-27% (poor) on nutrition and health respectively as compared to other staff with manager scoring the highest (69%). Amongst the various aspects of nutrition and health studied, most staff had excellent knowledge on food adulterants followed by ways to conserve nutrients while processing and cooking. Poor knowledge was exhibited by most workers at Jan aahar on aspects such as nutrients essential for growth, sources of protein, vitamins, minerals, value addition of foods and harmful effects of excessive heating of oil.

Table 5.4.3.3 shows the personal hygiene knowledge scores of Jan aahar kitchen staff. F-test showed a significant ($p<0.01$) difference amongst personal hygiene knowledge scores of Jan aahar kitchen staff. Excellent scores were obtained by maximum kitchen staff and only one waiter scored poorly for personal hygiene. Excellent scores (85-100%) for individual personal hygiene practices were obtained by all the staff members. Individual personal hygiene practice i.e. activities after which hand wash with soap is must, scored 100% by the kitchen staff.

Table 5.4.3.1: Knowledge scores on food hygiene aspects of kitchen staaf at Jan aahar

Food Hygiene aspects	Supervisor	Manager	Cook	Asst. cook	C 1	C 2	C 3	W 1	W 2	W 3	Total	% score	Individual knowledge score grades
4 food borne illnesses	3	2	3	2	2	1	2	3	3	4	**25**	**62.5**	**Good**
4 characteristics of spoiled food	4	4	4	3	4	3	4	3	4	4	**37**	**92.5**	**Excellent**
4 symptoms of food borne illness	4	4	4	2	3	4	4	4	2	4	**35**	**87.5**	**Excellent**
4 ways to prevent bacterial contamination while handling	3	4	4	4	3	4	4	3	3	3	**35**	**87.5**	**Excellent**
4 food contaminants which make food unsafe and unfit for consumption	4	3	3	3	3	4	4	2	3	4	**33**	**82.5**	**Excellent**
4 biological sources of food contamination	4	3	4	4	4	3	4	4	4	4	**36**	**90**	**Excellent**
4 ways to manage leftover food	3	2	2	3	2	1	0	2	3	3	**21**	**52.5**	**Fair**
4 ways of serving safe drinking water	3	2	3	3	3	2	2	2	3	3	**26**	**65**	**Good**
4 reasons to store raw material at dry place	3	3	4	1	3	4	2	2	4	4	**30**	**75**	**Very good**
4 reasons to cover cooked food	3	3	2	3	3	3	3	2	3	4	**29**	**72.5**	**Very good**
Total	**34**	**30**	**33**	**28**	**30**	**29**	**29**	**25**	**32**	**37**			
% score	**85**	**75**	**82.5**	**70**	**75**	**72.5**	**72.5**	**62.5**	**75**	**80**			
Staff grades	**Excellent**	**Very good**	**Excell -ent**	**Very good**	**Very good**	**Very good**	**Very good**	**Good**	**Very good**	**Very good**			
F-test-					**1.57^{NS}**								

Note: NS- not significant; 0-No response, 1-Unsatisfactory score, 2- Average score, 3- Satisfactory score, 4-Most satisfactory score; C-Cleaner; W-Waiter

Grade classification- Above 80-excellent; 70-80- very good; 60-69- good; 50-59- fair; less than 50- poor

Table 5.4.3.2: Knowledge scores on nutrition and health aspects of kitchen staff at Jan aahar

Knowledge on nutrition and health aspects	Supervisor	Manager	Cook	Asst. cook	C 1	C 2	C 3	W 1	W 2	W 3	Total	% Scores	Individual knowledge score grades
4 energy foods	3	3	3	2	3	2	2	2	1	2	**23**	**57.5**	Fair
4 ways to conserve nutrients while processing and cooking food	3	4	4	3	3	4	2	4	3	2	**32**	**80**	Very good
4 nutrients essential for growth and maintenance	1	4	2	0	0	0	0	0	0	0	**7**	**17.5**	Poor
4 food sources of protein	3	4	2	0	0	3	0	0	0	0	**12**	**30**	Poor
4 rich sources of vitamins	2	2	1	0	0	2	2	0	0	0	**9**	**22.5**	Poor
4 food adulterants	4	3	4	3	3	4	4	4	4	4	**37**	**92.5**	Excellent
4 sources of minerals	2	1	2	0	0	2	0	0	0	0	**7**	**17.5**	Poor
4 ways for value addition of the food products	0	0	0	0	3	2	0	0	0	0	**5**	**12.5**	Poor
4 harmful effects of excessive heating of oil	4	4	1	0	2	0	2	0	1	1	**15**	**37.5**	Poor
Total	**22**	**25**	**19**	**8**	**14**	**19**	**12**	**10**	**9**	**9**			
% Scores	**61**	**69.4**	**52.7**	**22.2**	**38.8**	**52.7**	**33.3**	**27.7**	**25**	**25**			
Staff grades	**Good**	**Good**	**Fair**	**Poor**	**Poor**	**Fair**	**Poor**	**Poor**	**Poor**	**Poor**			
F-test-					**1.93***								

Note: *-significant at p<0.05, 0-No response, 1-Unsatisfactory score, 2- Average score, 3- Satisfactory score, 4-Most satisfactory score; C-Cleaner; W-Waiter

Grade classification- Above 80-excellent; 70-80- very good; 60-69- good; 50-59- fair; less than 50- poor

Table5.4.3.3: Knowledge scores on personal hygiene of kitchen staff at Jan aahar

Personal Hygiene	Supervisor	Manager	Cook	Asst. cook	C 1	C 2	C 3	W 1	W 2	W 3	Total	% Scores	Individual knowledge score grades
4 protective clothes necessary for a food handler	4	4	4	3	4	3	4	0	4	4	**37**	**92.5**	**Excellent**
4 bad habits which should be prohibited by food handlers	4	4	4	3	4	3	3	0	4	4	**34**	**85**	**Excellent**
4 activities contaminate food with harmful germs	4	4	4	4	4	4	4	0	4	4	**36**	**90**	**Excellent**
4 activities after which hand wash with soap is must	4	4	4	4	4	4	4	4	4	4	**40**	**100**	**Excellent**
Total	**16**	**16**	**16**	**14**	**16**	**14**	**15**	**8**	**16**	**16**			
% Scores	**100**	**100**	**100**	**87.5**	**100%**	**87.5%**	**93.8%**	**50%**	**100%**	**100%**			
Staff grades	**Excellent**	**Excellent**	**Excellent**	**Excellent**	**Excellent**	**Excellent**	**Excellent**	**Fair**	**Excellent**	**Excellent**			
F-test-						**3.6****							

Note: **-significant at p<0.01, 0-No response, 1-Unsatisfactory score, 2- Average score, 3- Satisfactory score, 4-Most satisfactory score; C-Cleaner; W-Waiter

Grade classification- Above 80-excellent; 70-80- very good; 60-69- good; 50-59- fair; less than 50- poor

5.4.4: Observed practices of cooks, cleaners and waiters on personal hygiene

Cooks, cleaners and waiters were observed for practices such as wearing of protective clothes, their appearance, refraining from habits such as gutka eating, tobacco chewing, use of clean hand towels and clean nails. Based on the observation they were given a score of 3 for every satisfactory practice, 2 for average practice and 1 for unsatisfactory practice.

Table 5.4.4 reveals that there was no significant difference on observed personal hygiene practices of cooks, cleaners and waiters. The personal hygiene of cooks was poorer (48%) than other workers namely cleaners and waiters who scored better in the range of 63-70%. Except for assistant cook, all the staff of Jan aahar refrained from practices such as gutka eating and tobacco chewing. All the workers undertook a regular health check up. With regards to protective clothing none of the worker wore uniforms, head gears and gloves. No hand towels were used by the workers for wiping hands and a dirty linen was used after multiple activities including wiping hand after hand washing.

Table 5.4.4: Observed personal hygiene practices of cooks, cleaners and waiters at Jan aahar

Personal Hygiene	Cook	Asst. cook	C 1	C 2	C 3	W 1	W 2	W 3	Total	% scores	Individual knowledge score grades
The food handlers have uniform, head gear, apron and towel	1	1	1	1	1	2	2	2	**11**	**34.4**	**Poor**
Overall appearance of food handlers is clean	1	1	2	2	2	2	2	2	**14**	**43.8**	**Poor**
Washing with soap after toilet/personal work	2	2	3	3	1	1	2	2	**16**	**50**	**Fair**
Dresses of the employees are clean	2	2	2	2	2	3	3	2	**18**	**56.3**	**Fair**
Nails of the workers are clean	1	1	2	2	3	3	2	1	**15**	**46**	**Poor**
No smoking, gutka eating and tobacco chewing by the staff while working	3	1	3	3	3	3	3	3	**22**	**68.8**	**Good**
Dry hands with separate towel/napkins for the same	1	1	2	2	1	1	1	1	**10**	**31.2**	**Poor**
Use of mask while cooking and serving	1	1	1	1	1	1	1	1	**8**	**25**	**Poor**
Whether health check up was done before or during service	3	3	3	3	3	3	3	3	**24**	**100**	**Excellent**
Total	**15**	**13**	**19**	**19**	**17**	**19**	**19**	**17**			
% scores	**55.5**	**48.1**	**70.3**	**70.3**	**62.9**	**70.3**	**70.3**	**62.9**			
Staff grades	**Fair**	**Poor**	**Very good**	**Very good**	**Good**	**Very good**	**Very good**	**Good**			
F-test-					**0.77^{NS}**						

Note: NS-non significant, 1-Unsatisfactory score, 2- Average score, 3- Satisfactory score; C-Cleaner; W-Waiter

Grade classification- Above 80-excellent; 70-80- very good; 60-69- good; 50-59- fair; less than 50- poor

5.4.5: Available infrastructure facility on food hygiene, unit hygiene and environmental hygiene at Jan aahar

Satisfactory food hygiene practices shown in Table 5.4.5 (a), were observed for sorting of grains, removal of unwanted portion, use of clean knives, use of refrigerator for storage etc. However, practices such as adequate washing of vegetables, covering of foods after cooking and labeling of foods was found to be unsatisfactory.

With respect to unit hygiene it was observed that the service counters were not cleaned frequently and the washbasin appeared dirty. However, the kitchen floor was mopped after every shift. Further, satisfactory environmental hygiene was observed such as dining area was clean and free from flies and insects, daily use of disinfectants and no human disposal near the restaurant.

Regarding the observed infrastructure facilities available at Jan aahar, it can be seen in Table 5.4.5 (b) that satisfactory scores were obtained for amenities like use of stainless steel knives, commercial detergents for washing utensils, glazed kitchen top, floor, running tap water facility, use of smokeless fire and fuel for cooking, white wash of walls, roof, store, kitchen etc. However, facilities found to be average and unsatisfactory include clean cloth was not present for moping tables, counters; no soap and clean towel was present at washbasin, not availability of geyser for washing utensils, no separate store for raw materials and the kitchen had no ventilators and chimney indicating a further need of improvement in the studied catering joint.

Table 5.4.5 (a): Observed practices of available infrastructure facility on food hygiene, unit hygiene and environmental hygiene in Jan aahar

(a) Practices	Unsatisfactory	Average	Satisfactory
Food hygiene			
Use of running water for washing of raw materials			3
Sorting and removal of unwanted portion, ingredient before cooking and processing		2	
Chopping and peeling only after proper washing	1		
Use of clean knifes, cutter and chopping board for vegetables, salads		2	
Every item is covered before cooking, during cooking and after cooking	1		
Spices, food ingredients were clean and labeled	1		
Use of chilling facilities/refrigerator for storage		2	
Cooked food was stored in stainless steel vessels		2	
All serving and dining vessels were covered and kept at a dry place		2	
Running water was provided for washing and cooking			3
Total score			
% score	**3**	**10**	**6**
Unit hygiene	**30**	**50**	**20**
Utensils are washed immediately after use			3
Presence of neat and clean wash basin	1		
Service counter was cleaned frequently	1		
Washing and mopping of floor after every shift			3
Total	**2**	**0**	**6**
% score	**50**	**0**	**50**
Environmental hygiene			
Dining table and hall is free from flies and insects			3
Surrounding are clean and free from flies and insects			3
Daily use of disinfectant for cleaning of surrounding			3
Facility for driving pets out		2	
No animal/human disposal near restaurant			3
Total	**0**	**2**	**12**
% score	**0**	**20**	**80**

Table 5.4.5 (b): Observed available infrastructure facilities in Jan aahar

(b) Infrastructure facility	Unsatisfactory	Average	Satisfactory
The restaurants had separate store for raw materials		2	
Use of stainless steel knives			3
Commercial detergents are used for washing utensils			3
Clean cloth is used for moping of tables, counters etc.	1		
Wash basin has running tap water facility			3
Wash basin has soap/liquid soap	1		
Wash basin has clean and dry towels	1		
Food service unit is dust, dirt and smoke free	1		
Use of smokeless fire and fuel for cooking			3
The kitchen had exhaust fan, ventilators and chimney		2	
Hot water/ geysers facility is available	1		
Water purifier facility was provided for drinking water	1		
Service counter had glazed surface	1		
Detergent and tools used for washing of kitchen top, ground floor, sinks, stores etc. after every shift			3
White wash of walls, roofs, stores, kitchen etc.			3
Dining place covered, ventilated and lighted			3
No garbage near the restaurant			3
Disposal of garbage in waste bins having proper lids	1		
Total	**8**	**4**	**24**
% score	**44.4**	**11.1**	**44.4**

5.4.6: Oil procurement, storage and frying practices at Jan aahar

Cottonseed oil was used by cooks for frying and other cooking purposes. Cooking oil was procured in jerry cans from wholesale shops of Vadodara. Twenty liters oil was purchased at a time which lasted for 5 days. Cooking oil was stored at open area of kitchen. As told by the head cook and asst. cook, loose oil was not purchased due adulteration. Before purchase of cooking oil, expiry date of oil was monitored as told by the cooks, however they did not know the shelf life of packed oil.

Frying practices of cooks: Frying practices of cooks was assessed as shown in Table 5.4.6. It found that both the cooks did not know the correct frying temperature and had no idea how to measure frying oil temperature. Iron and hindalium vessels were used for frying food products as reported by both the cooks. Frying vessels were cleaned daily with hot water and dish cleaning soap. Both the cooks had good knowledge about the deterioration of oil quality such as foaming, color change, change in consistency of fried oil. Cooks reported that fried food particles from oil were removed before every frying. Leftover fried oil was filtered, not reused for frying purpose and was stored in stainless steel jars for other purposes like sautéing.

Table 5.4.6: Frying practices of cooks at Janaahar- a food joint at Vadodara railway station

Practices	Head cook	Asst. cook
a) Have you ever measured frying temperature? Yes/No	No	No
b) Are you aware of correct frying temperature? Yes/No	No	No
c) If yes, what is the correct frying temperature? i)100^{0}C ii) 160^{0}C iii)180^{0}C iv) 250^{0}C	--	--
d) Do you know how frying temperature is measured?	Do not know	Do not know
e) What type of frying vessel is used for frying? i) Iron ii) Stainless steel iii) Hindalium	Iron	Iron
f) How often you clean you frying vessel? i) Daily ii) 2-3 times a week iii) Once a week iv) After a week, specify	Daily	Daily
g) Do you know how frying vessel should be cleaned? Yes/No	Yes	Yes
h) If yes, how? i) with water only ii) with water and dish cleaning soap iii) with water and caustic	With hot water and dish cleaning soap	With hot water and dish cleaning soap
i) Do you know change in color is an indicator of deterioration of oil quality? Yes/No	Yes	Yes
j) Do you know foaming in is an indicator of deterioration of oil quality? Yes/No	No	No
k) Do you know change in consistency is an indicator of deterioration of oil quality? Yes/No	Yes	Yes
l) Is the presence of food particles in fried oil is an indicator of deterioration of oil quality? Yes/No	Yes	No
m) What do you do with food particles in oil? i) separate them from oil before frying every time ii) do not separate them from oil and fry in same oil	Separate them from oil before frying every time and throw them	--
n) Do you add fresh oil in fried oil? Yes/No	No	Yes
o) One batch of oil should be fried for how many hours? i) 2 h ii) 4 h iii) 8 h iv) More	8 hours	8 hours
p) Do you store leftover fried oil? Yes/No	Yes	Yes
q) If yes, in which utensil i) Same pan in which the food was fried ii) Plastic container iii) Stainless steel jar iv) Other utensil	--	Stainless steel jar
r) Practice of storing fried oil i) Filtered ii) Without filter	Filtered	Filtered

PHASE IV - RESULT HIGHLIGHTS

- *Jan aahar, a catering outlet is situated at western zone railway station-Baroda.*
- *Jan aahar caters approximately 250 customers daily. Currently it is running in loss at the rate of 2 laks 40 thousand rupees/month.*
- *A total of 10 kitchen staff members are presently working and only 4 members have gone through with food safety training.*
- *Food hygiene knowledge of Jan aahar kitchen staff showed no significant difference. However, supervisor, manager and head cook scored maximum for food hygiene.*
- *Amongst the various aspects of food hygiene knowledge, correct way to manage leftover food was fairly known (52%) by all the kitchen staff.*
- *A significant difference ($p<0.05$) was observed amongst the knowledge scores on nutrition and health of kitchen staff. Waiters and assistant cook obtained lowest scores 22-27% (poor) on nutrition and health respectively as compared to other staff with manager scoring the highest (69%).*
- *Poor knowledge was exhibited by most workers at Jan aahar on various aspects of nutrition and health.*
- *Significant ($p<0.01$) difference amongst personal hygiene knowledge scores of Jan aahar kitchen staff.*
- *Excellent scores (85-100%) for individual personal hygiene practices were obtained by all the staff members.*
- *No significant difference was observed on personal hygiene practices of cooks, cleaners and waiters.*
- *Except unit hygiene, satisfactory food hygiene and environmental hygiene was observed. Infrastructural facilities like clean cloth, moping cloth for tables, counters, geyser for washing utensils, separate store for raw materials etc. were lacking.*
- *Both the cooks did not know the correct frying temperature. Although cooks had good knowledge about the deterioration of oil quality during frying.*

DISCUSSION

The nutritional status, health, physical and mental faculties depend on the food we eat and how we eat it. Access to good quality food has been man's main endeavor from the earliest days of human existence. Safety of food is an inherent component of food quality.

Food joints such as restaurants, street food vendors, *dhabas*, fast food joints, railway and bus stand food outlets have come to stay in today's contemporary world, due to increased need for food outside home, be it for people who are migrating for educational purpose or for other purposes and are considered as an important source of food borne outbreaks. Unhygienic preparation of food in such places provides ample opportunities for contamination, growth, or survival of food borne pathogens that may lead to diseases commonly referred as food borne illness. According to Mazumdar S (1992) 40% of the food borne illness is caused by mishandling of food and cross contamination in catering establishments.

People have the right to accept the food they eat to be safe and suitable for consumption. The importance of safe food for health and development has been recognized and addressed in many international fores as well. Safe food is one of the three essentials for maintenance of life and health. "Food safety" implies absence of biological contaminants, adulterants, naturally occurring toxins or any other substance beyond safety limits and that, which may make food injurious to health on an acute or chronic basis.

In view of above, the present work was undertaken to study the food safety knowledge of kitchen staff and practice of kitchen staff with respect to food hygiene, personal hygiene, unit hygiene etc. at Jan aahar-a food joint at Vadodara railway station.

The present study revealed that knowledge on food hygiene of kitchen staff at Jan aahar was excellent for most studied aspects. This could be because of food safety training taken by the senior kitchen staff working at Jan aahar. According to WHO, the most important cause of the spread of food borne disease is the poor knowledge on food safety and unhygienic methods adopted by food handler. In order to prevent the food disease outbreaks food safety education to food handlers should be imparted. A study on the knowledge, attitude and practices of food service staff regarding food hygiene in Iran reported that the personnel had little knowledge regarding pathogens that cause food borne diseases and the correct temperatures for the storage of hot or cold ready to eat food (Askarin M et al, 2004).

With regards to personal hygiene knowledge maximum kitchen staff gained excellent scores. However, the observed personal hygiene of most staff was not satisfactory. Study by Olsen et al found that annually from 1993 to 1997, poor personal hygiene of food workers was a contributing factor in 27 to 38% of food borne illness outbreaks. Difference in knowledge and observation scores in the present study may perhaps due to lack of interest in following the food safety rules or ignorance could be the other reason. Study by Sheth M, Gupta A and Ambegaonkar T in 2011 reported personal habits of unsupervised food handlers working in a restaurant was poor where the staff resorted to tobacco chewing and eating beetle leaf and/or beetle nut and habit of smoking. Such unhygienic practices may introduce a variety of micro organisms in food (Kudu and Mishra, 2003). Present study has revealed better personal hygiene of Jan aahar staff than the above reported study. This could be because of good control by the supervisor at Jan aahar. In another study by Sheth M, Sukul S and Patel R (2007) reported that majority of the kitchen staff working in University Boy's hostel of Vadodara city, India, had poor personal hygiene with regard to dirty nails and moustache.

Knowledge on nutrition and health aspects of Jan aahar kitchen staff was poor indicating a need for proper training on this aspect. In a study undertaken to train street food vendors on food safety with a component of nutrition and health showed very good knowledge on nutrition and health prior to the training which improved significantly after the training (Sukul S and Sheth M, 2010). Nutrition and health component of kitchen staff of most kitchen food services establishments is found to be very poor. However, training imparted on this aspect improved their knowledge on nutrition and health (Malhotra R et al, 2008; Meer RR and Misner SL, 2000; Cox et al, 2003).

The infrastructure facility of Jan aahar was found unsatisfactory in many aspects and hence is a cause of concern from food safety point of view. WHO report on survey of street vended foods revealed that the most critical problems in street vending is provision of infrastructural facilities like supply of safe drinking water, sufficient quantity of water for washing, cleaning and other operations. WHO (1996), reported that countries under study had limited infrastructure developments with restricted access to potable water (47%), toilets (15%), refrigeration (43%) and washing and waste disposal facilities.

Regards to oil procurement and frying practices, satisfactory responses were obtained by the cooks of Jan aahar. In a cross-sectional survey on food outlet operators (n=100) of Kuala Lumpur showed that food operators had moderate (53%) knowledge regarding usage of repeated heated cooking oil their detrimental effects on health (Azman A et al, 2012). In addition, a recent Indian study by Goyal N and Sundararaj P (2009) has shown the use of abused oil being used by many restaurants and food outlets. However, in the present study, cooks at Jan aahar did not reuse the oil for frying.

Hence, the present work has thrown light on existing infrastructure facility of Jan aahar and the knowledge levels and practices of the staff of Jan aahar on various food safety aspects. With a regular food safety training program the knowledge level of the staff can be improved. The railway ministry needs to work on improving the infrastructure facility.

PHASE III

5.3: CHEMICAL CHANGES DUE TO THERMAL DEGRADATION OF INTERMITTENTLY DEEP FRIED COTTONSEED OIL (CSO) AND GROUNDNUT OIL (GNO) AS A RESULT OF FRENCH FRIES AND BHAJIAS FRYING

Deep-fat frying is one of the oldest and popular food preparations because it is fast, convenient, and such foods are generally liked for flavor and texture. Deep-fat frying is more a technology than science. Deep-fat frying can be defined as process of controlled dehydration and browning with hot oils as the heat transfer medium (Singh S and Tyagi VK, 2001). It involves both mass transfer and heat transfer.

During deep-fat frying, the oil is continuously or repeatedly used at elevated temperature in the presence of air. During frying, a variety of reactions cause a spectrum of physical and chemical changes. In the presence of oxygen from either the air or the product, food moisture, and high temperature, oil undergoes mainly three deleterious reactions: hydrolysis caused by water, oxidation and thermal alterations caused by oxygen, and heat, respectively (Nawar WW, 2000).

A significant proportion of edible oils are used worldwide for deep-fat frying for various foodstuffs. The decomposition products developed as a result of deep frying are however a cause of concern from health point of view. In view of this, III phase of the present study comprised of determining the thermal degradation of two popular consumed oils in Gujarat viz. a viz. cottonseed and groundnut oil fried at intermittent durations. Refined cottonseed and double filtered groundnut oil was heated up to 180^0C for frying french fries and bhajias at intermittent intervals for 25 h (actual frying 2.5 h). 75ml of fried cottonseed and groundnut oil was pipette out at the end of each day (0, 5, 10, 15, 20 and 25 h) and assessed for its chemical and physical parameters. Average temperature maintained in CSO and GNO during frying french fries (CSO and GNO) and bhajias (CSO and GNO) is shown in Figure 5.3.1 and 5.3.2 respectively.

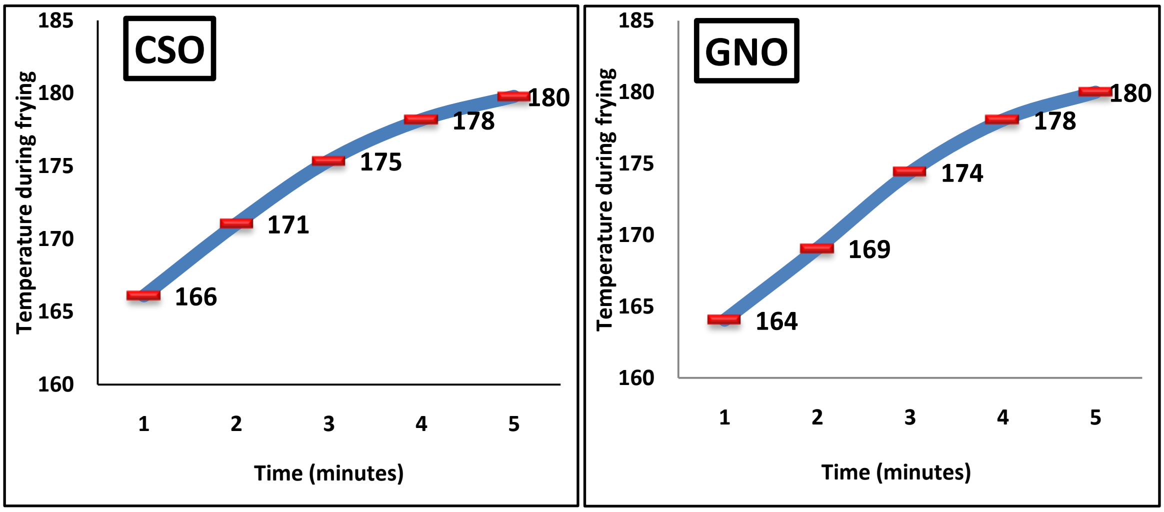


Figure 5.3.1: Rise in average temperature during frying of french fries in CSO and GNO

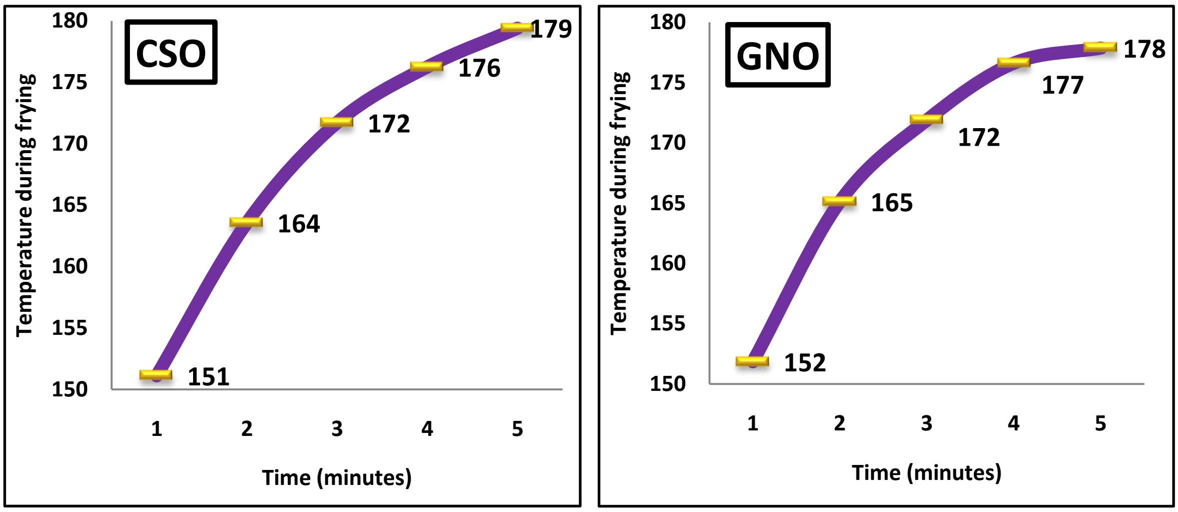


Figure 5.3.2: Rise in average temperature during frying of bhajias in CSO and GNO

The results of this phase are presented under the following heads:

5.3.1: Intermittent frying stability of CSO and GNO used for frying french fries in terms of its breakdown products

5.3.2: Intermittent frying stability of CSO and GNO used for frying bhajias in terms of its breakdown products

5.3.3: Correlation of french fries and bhajias sensory attributes with chemical parameters of french fries and bhajias fried CSO and GNO

5.3.1: Intermittent frying stability of CSO and GNO used for frying french fries in terms of its breakdown products

A. Chemical parameters

I. Peroxide value (PV)

As seen in Figure 5.3.1.1, at 0 h the primary oxidation (PV) of CSO was significantly higher ($p>0.001$) than GNO when compared to limits of <10meq O_2/kg (Ranganna S, 2003). Thereafter PV progressively increased in both the oils but GNO had significant higher ($p<0.01$) value at 10 h of intermittent frying. However, at 25 h of frying duration GNO showed lower peroxide values than CSO though the difference was not statistically significant. The percent increase in PV for CSO and GNO was 98.4% and 308.2% respectively. Student 't' test showed a significant ($p<0.05$) difference in CSO and GNO PV at 0 and 10 h of intermittent frying (Appendix 11.4a).

Regression equations have indicated positive correlation between the frying time and PV for both the oils (Figure 5.3.1.2).

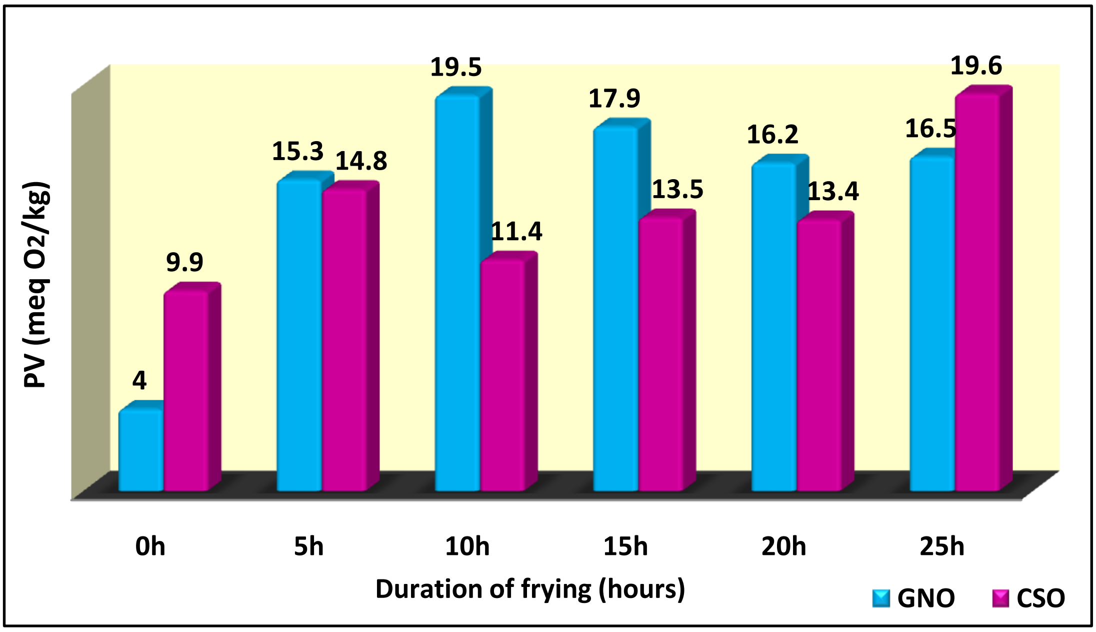


Figure 5.3.1.1: Peroxide value of CSO and GNO at intermittent frying intervals

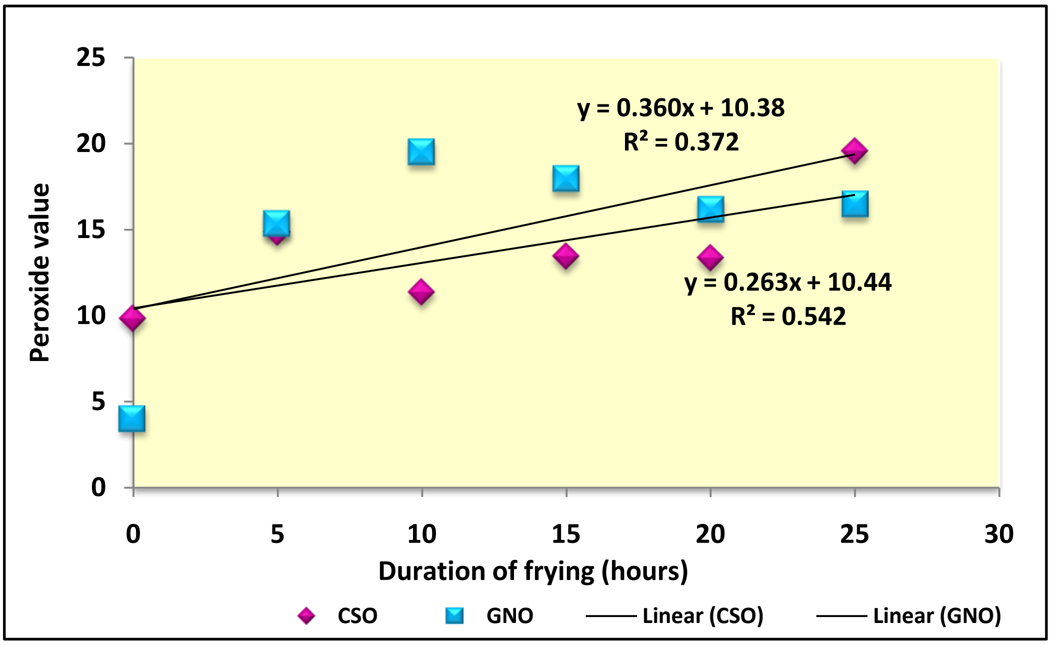


Figure 5.3.1.2: Relation between peroxide value and duration of frying

II. p-anisidine value (p-AV)

CSO at 0 h showed significantly higher ($p<0.001$) p-anisidine value than GNO (Figure 5.3.1.3). Generally the p-AV of good quality oil should be less than 2.0 (Bhattacharya AB et al, 2008). p-AV mainly accounts as degradation products of peroxides rose significantly ($p<0.001$) to 93.3 and 53.61 in CSO and GNO respectively at 5 h of frying duration, which continued to increase thereafter up to 25 h. p-AV of CSO remained significantly higher ($p<0.001$) than GNO during the entire period of frying (Appendix 11.4a). Peroxide and p-anisidine values also showed a strong correlation of r=0.78 (GNO) and r=0.66 (CSO).

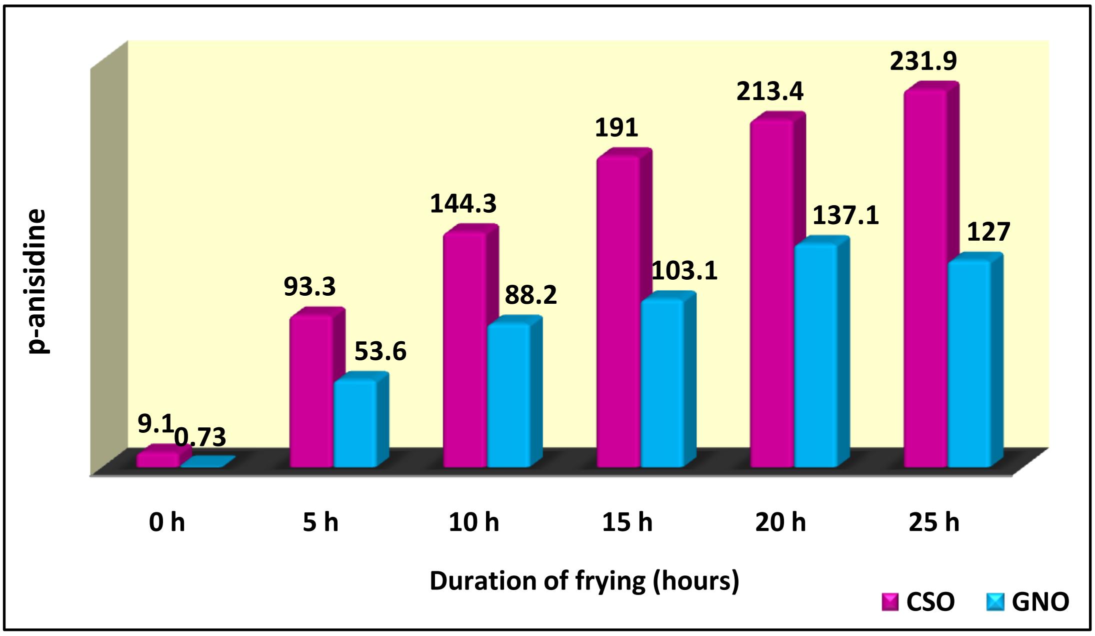


Figure 5.3.1.3: p-anisidine value of CSO and GNO at intermittent frying intervals

p-anisidine values strongly correlated with frying duration for both, GNO (r^2=0.89) and CSO (r^2=0.93) as shown in Figure 5.3.1.4.

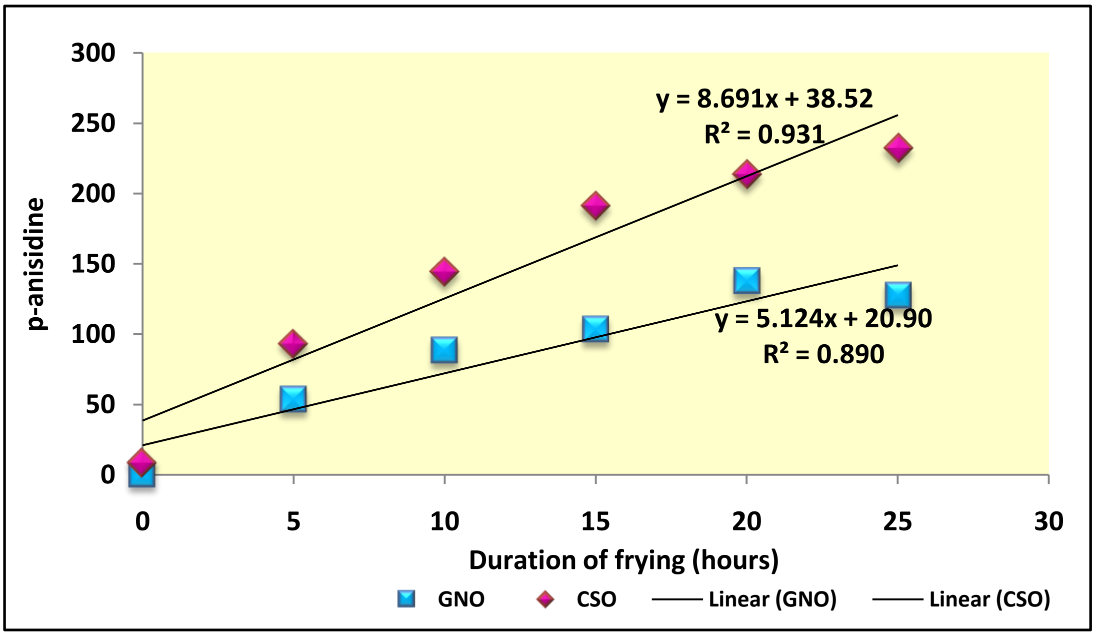


Figure 5.3.1.4: Relation between p-anisidine value and duration of frying

III. Totox value (TV)

The TOTOX (i.e. total oxidation products) value of both the oils used for french fries frying was significantly ($p<0.001$) increased (Table 5.3.1.1). ANOVA value of CSO showed higher oxidation products than GNO.

Table 5.3.1.1: Totox value of GNO and CSO at intermittent intervals of french fries frying

Duration of frying (hours)	Totox value	
	GNO	CSO
0 h	8.77±1.0[a]	28.7±8.2[a]
5 h	84.25±9.6[b]	122.9±2[b]
10 h	127.1±6.7[c]	167.1±2[c]
15 h	138.9±8.9[c]	217.9±5[d]
20 h	169.4±2.9[d]	240.1±8.6[e]
25 h	159.6±5.1[e]	270.9±6.6[f]
F-value	**339.77*****	**859.17*****

Note: *-Significant at p<0.001; The superscripts with similar alphabets in each row indicate no significant difference between the values**

IV. Iodine value (IV)

Iodine value, a measure of overall unsaturation and is widely used to characterize oils and fats. It is expressed in terms of the number of milligrams of iodine absorbed/g of the sample (AOAC, 1995). Vegetable oil products order (VOPO) has laid down the standard limit for GNO and CSO between 85 to 99 and 98 to 112 respectively (VOPO, 1998).

Iodine value, at 0 h of both the oils was found within the suggested limits. A statistically significant ($p<0.001$) decrease, CSO (3.2%) and GNO (3.6%) was observed at the end of 5 h of intermittent frying (Table 5.3.1.2). Iodine value of CSO crossed the lower limit (95.33) at 10 h of frying duration but GNO remained stable. However, at 25 h of intermittent frying GNO crossed the lower limit (81.36) set by VOPO. A total of 14.45% and 17.64% decrease was observed in CSO and GNO respectively at the end of 25 h of intermittent frying period.

Table 5.3.1.2: Iodine value (mg I_2/g of oil) of GNO and CSO at intermittent intervals of french fries frying

Duration of frying (hours)	Iodine value GNO	Iodine value CSO
0 h	98.79±0.31[a]	102.38±0.36[a]
5 h	95.23±0.51[b]	99.1±0.8[b]
10 h	89.9±0.49[c]	95.33±0.61c
15 h	87.89±0.44[d]	91.36±0.65[d]
20 h	86.1±1.87[d]	87.3±0.78[e]
25 h	81.36±0.79[e]	87.58±2.38[e]
F-value	**194.52****	**116.77****

Note: **- significant at p<0.01; The superscripts with similar alphabets in each row indicate no significant difference between the values

Figure 5.3.1.5 shows a strong relation between IV and increased frying time in both the oils (CSO r^2=0.96, GNO r^2=0.97).

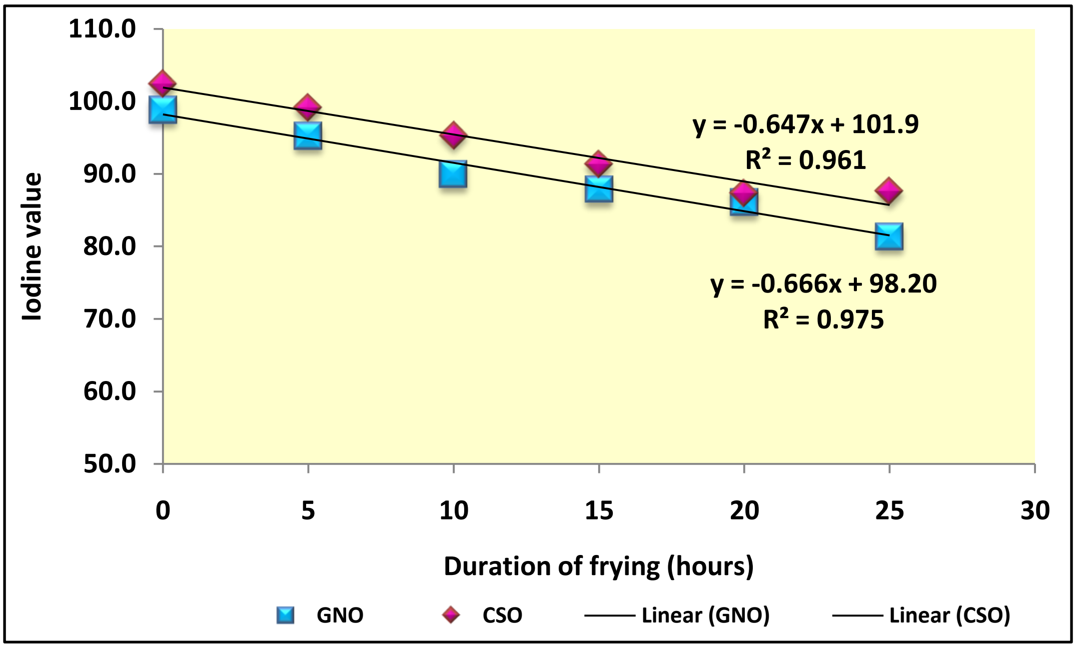


Figure 5.3.1.5: Relation between Iodine value and duration of frying

V. Acid value (AV)

Acid value, a hydrolytic parameter used to assess degradation of frying oils is shown in Table 5.3.1.3. The initial acid value of both the oils was within the set limits, suggested by VOPO i.e. for GNO acid value was <6 mg KOH/g and <0.5 mg KOH/g of sample for CSO (Vegetable oil products order, 1998).

The AV was found to be different in both the samples at initial levels because of different grades of oils i.e. refined (CSO) and filtered (GNO). At the end of 5 h of intermittent frying, AV increased by 20% in both the oils. Increase in hydrolytic changes of both the oils at the end of intermittent frying was statistically significant ($p<0.001$). AV of CSO at 20 h of frying interval was very close to the standard limit and reached to 0.80 mg KOH/g at 25 h of frying. However, the hydrolytic degradation in GNO was within limits of VOPO even after 25 h of intermittent frying. Increased frying time showed a strong relation with AV (Figure 5.3.1.6) of both the fried oils with $r^2=0.90$ for CSO and $r^2=0.91$ for GNO respectively.

Table 5.3.1.3: Changes in acid value (mg KOH/g) of GNO and CSO at intermittent intervals of french fries frying

Duration of frying (hours)	Acid value	
	GNO	CSO
0 h	$0.60±0.02^{a}$	$0.10±0.01^{a}$
5 h	$0.72±0.08^{b}$	$0.12±0.05^{a}$
10 h	$0.83±0.06^{b}$	$0.20±0.03^{b}$
15 h	$1.04±0.18^{bc}$	$0.36±0.02^{c}$
20 h	$1.13±0.19^{bc}$	$0.49±0.03^{d}$
25 h	$1.62±0.36^{bc}$	$0.80±0.10^{e}$
F-value	**15.389****	**111.00****

Note: **Significant at -p<0.01; The superscripts with similar alphabets in each row indicate no significant difference between the values

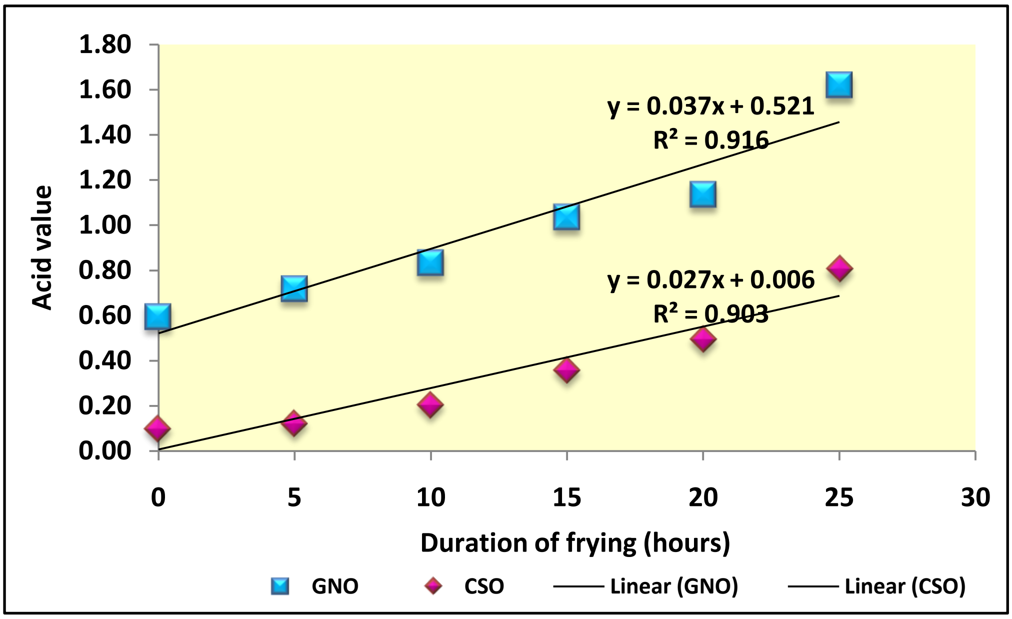


Figure 5.3.1.6: Relation between acid value and duration of frying

VI. Total polar components (TPC)

The content of total polar compounds determined by gravimetric separation of non-polar components using column chromatography is shown in Figure 5.3.1.7. At 0 h the TPC of CSO was significantly higher ($p<0.001$) than GNO. At 15 h of intermittent frying the TPC of CSO was 98.5% higher than GNO. At 25 h, the TPC show a total 83.8% and 89.4% increase in CSO and GNO respectively from the baseline values, which was still below the safe limits set by many European countries (Singh S and Tyagi VK, 2001). Plate 5.3.1.1 shows the thin layer chromatograph used to check the efficiency of column chromatography.

A strong correlation was observed between polar components and duration of frying ($r^2=0.99$ for CSO and $r^2=0.91$ for GNO) (Figure 5.3.1.8). CSO had significant higher ($p<0.001$) values than GNO at 0, 15 and 25 h of intermittent frying (Appendix 11.4a).

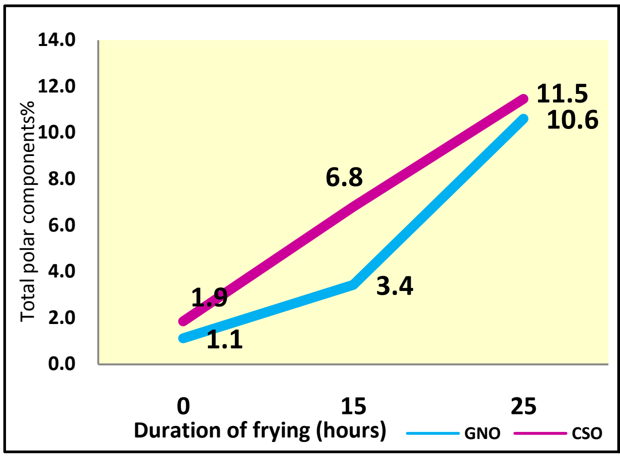


Figure 5.3.1.7: Total polar components (%) at intermittent frying intervals

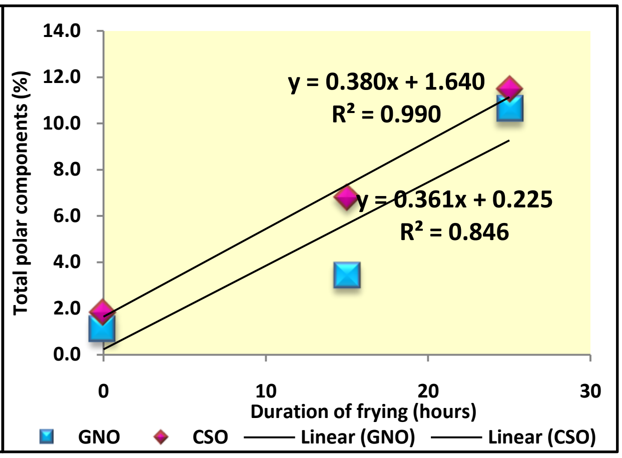


Figure 5.3.1.8: Relation between Total polar components and duration of frying

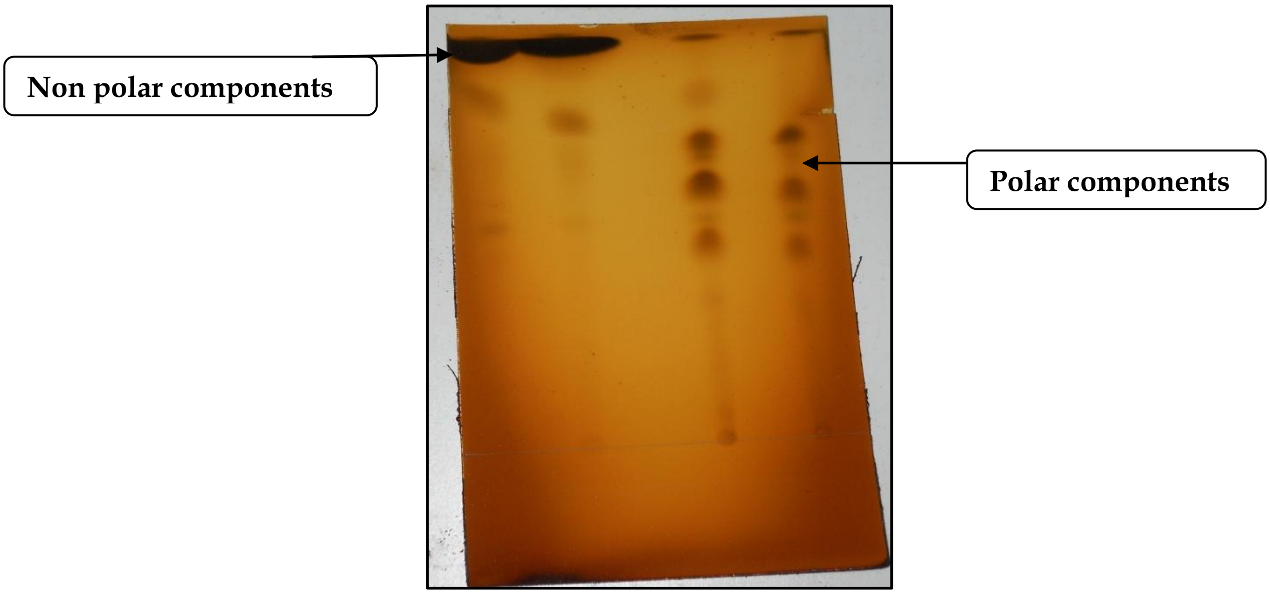


Plate 5.3.1.1: Thin layer chromatograph shows the polar and non polar components separated by column chromatography from french fried CSO

VII. Fatty acid profile

The saturated fatty acid content of CSO and GNO significantly increased with the increase in frying hours (Table 5.3.1.4). Palmitic acid increased up to 16.4% and 11.8% in CSO and GNO respectively at the end of 25 h intermittent frying. No significant change was observed in palmitoleic acid of both the fried oils. Increase in stearic acid was not significant in CSO, however stearic acid in GNO increased significantly ($p<0.01$). The major fatty acid of GNO, the oleic acid (n-9) increased by 4.4% and linoleic acid showed a decrease of 26% at the end of 25 h intermittent frying. However, no significant (student 't') increase was observed in oleic acid at 15 h and 25 h of frying duration of GNO. CSO rich in linoleic acid (n-6) decreased by 12.7% at 25 h of intermittent frying and oleic showed a significant increase ($p<0.01$) of 9.2%. Linolenic acid in GNO was totally missing with increased frying time. In the present study, significant decrease ($p<0.001$) and ($p<0.01$) was observed in 18:2/16:0 ratio by 33.8% and 25% in GNO and CSO respectively.

Fatty acid profile chromatograms of French fries fried GNO and CSO at 0 and 25 h are shown in Plate 5.3.1.2.

Table 5.3.1.4: Fatty acid profile (g/100 g fat) of cottonseed oil (CSO) and groundnut oil (GNO) at intermittent intervals

Fatty Acids		Frying Time (hours)			F-value
		0 h	15 h	25 h	
16:0 (Palmitic)	CSO	24.0±0.06^{a}	26.1±0.20^{b}	27.9±0.16^{c}	346.8***
	GNO	9.78±0.45^{ab}	10.5±0.09^{ab}	10.9±0.07^{abc}	9.5*
16:1 (Palmitoleic)	CSO	0.60±0.01	0.63±0.01	0.66±0.03	6.05^{NS}
	GNO	0.06±0.08	0.09±0.01	0.08±0	0.31^{NS}
18:0 (Stearic)	CSO	2.9±0.02	2.9±0.21	3.1±0.12	1.5^{NS}
	GNO	3.1±0.04^{a}	3.2±0.01^{b}	3.4±0^{c}	114.1**
18:1 (Oleic)	CSO	18.6±0.07^{a}	19.7±0.18^{b}	20.3±0.06^{c}	107.7**
	GNO	58.7±0.16^{a}	60.8±0.54^{b}	61.3±0.06^{b}	34.4**
18:2 (Linoleic)	CSO	50.9±0.18^{a}	47.1±0.30^{b}	44.4±0.15^{c}	435.8***
	GNO	21.9±0.31^{a}	18.8±0.62^{b}	16.2±0.59^{b}	58.0**
18:3 (Linolenic)	CSO	0.34±0.01^{a}	0.37±0^{b}	0.39±0.01^{b}	39.5**
	GNO	0.21±0.02	ND	ND	-
18:2/16:0	CSO	2.1±0.01^{a}	1.8±0^{b}	1.5±0.01^{c}	1739.4***
	GNO	2.2±0.08^{a}	1.7±0.08^{b}	1.4±0.06^{b}	54.4**

Note: *-Significant at p<0.05, **- Significant at p<0.01, *- Significant at p<0.001, NS- not significant, ND-not detected; Mean ± SD followed by the same superscript in each row are not significantly different**

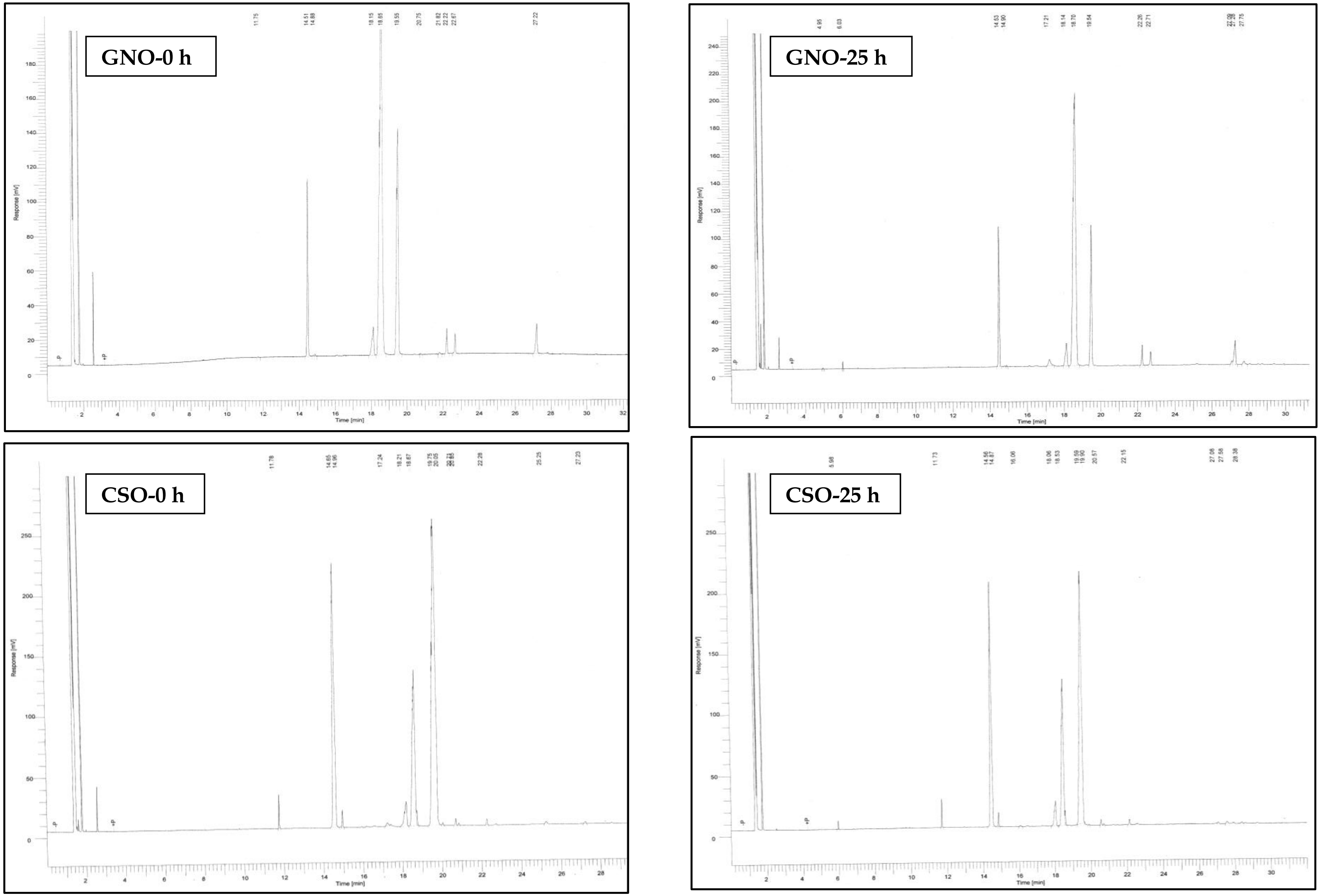


Plate 5.3.1.2: French fries fried GNO and CSO fatty acid profile chromatograms obtained at 0 and 25 h of intermittent frying

B. Physical parameters

I. Refractive index

The refractive index of fried oil is reported in Figure 5.3.1.9. The refractive index of GNO and CSO at 0 h was 1.4524 and 1.46405 respectively. Recommended refractive index in GNO is 1.4620-1.4640 and in CSO is 1.4630-1.4660 (VOPO, 1998). The refractive index of both the oils increased significantly ($p<0.001$) at the end of 25 h of frying duration. Both oils crossed the upper recommended limit at 25 h duration. Increased frying time showed a strong relation with refractive index (Figure 5.3.1.10) of both the fried oils with $r^2=0.99$ for CSO and GNO.

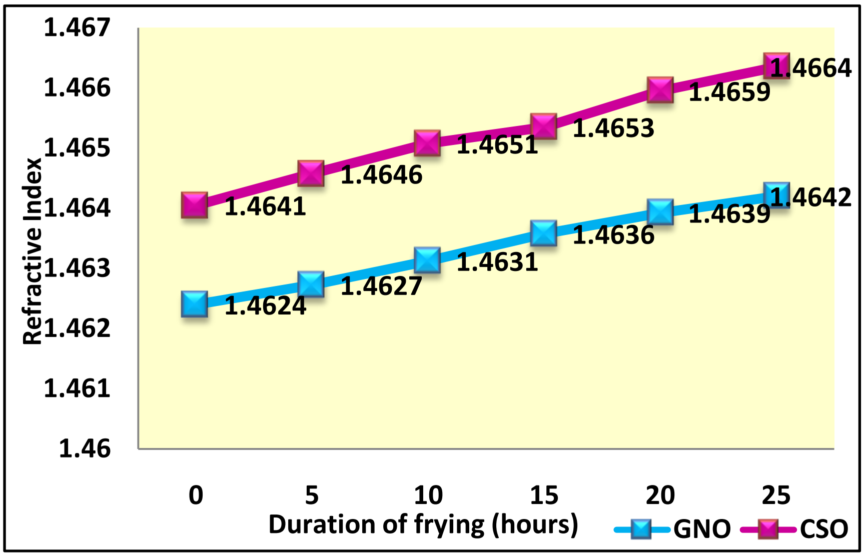


Figure 5.3.1.9: Refractive index of GNO and CSO at intermittent frying intervals

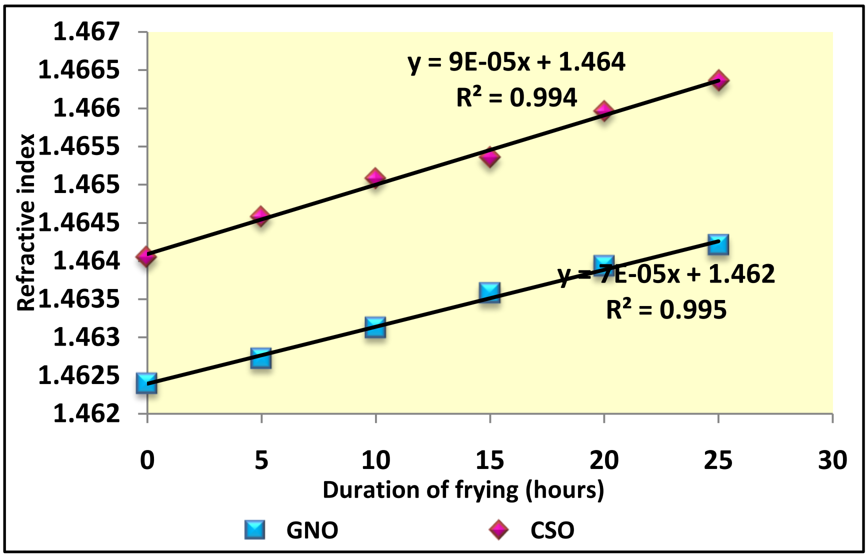


Figure 5.3.1.10: Relation between refractive index and duration of frying

II. Color

Change in color of fried oil is shown in Table 5.3.1.5. ANOVA analysis indicated significant increase ($p<0.001$) in color of both the oils during 25 h of intermittent frying. Student 't' showed no significant difference in color of both the oils up to 5 h of intermittent frying. After that a significant ($p<0.05$) increase in both yellow (Y) and red (R) color of GNO and CSO was noticed. Plate 5.3.1.4 shows the color of GNO before frying and 5.3.1.5 shows the change in color of french fries fried GNO.

Table 5.3.1.5: Change in color of GNO and CSO at intermittent intervals of french fries frying

Duration of frying (hours)	GNO		CSO	
	Y	R	Y	R
0 h	2.75±0.65^{a}	5.5±0.48^{a}	2±0^{a}	6.5±0.48^{a}
5 h	2±0.29^{a}	7±0.28^{a}	2.75±0.42^{b}	5.5±0.48^{a}
10 h	2.08±0.30^{a}	10±0^{b}	3.75±0.41^{c}	11±0.65^{b}
15 h	2.38±0.57^{abc}	11±0.5^{b}	4.2±0.18^{cd}	11.5±0.25^{bc}
20 h	3.53±0.52^{abc}	10.5±0.48^{b}	4.35±0.25^{d}	14±0.41^{bd}
25 h	3.73±0.50^{abc}	13±0.29^{bc}	4.83±0.17^{e}	15±0.29^{bd}
F-value	**8.57*** **	**13.03*** **	**58.06*** **	**18.87*** **

Note: *-significant at p<0.05, **- significant at p<0.01, *- significant at p<0.001; Mean ± SD followed by the same superscript in each row are not significantly different**

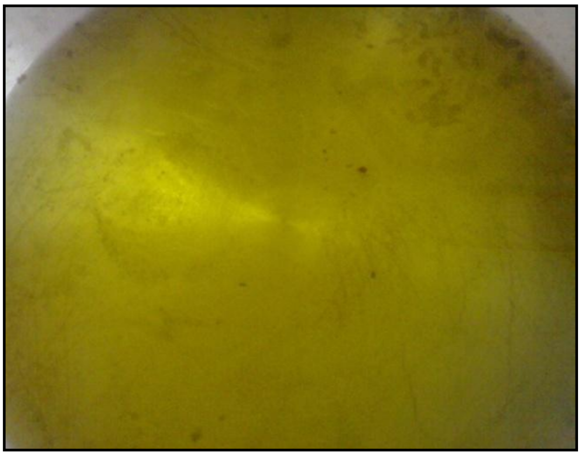


Plate 5.3.1.4: GNO color before 25 h of intermittent french fries frying

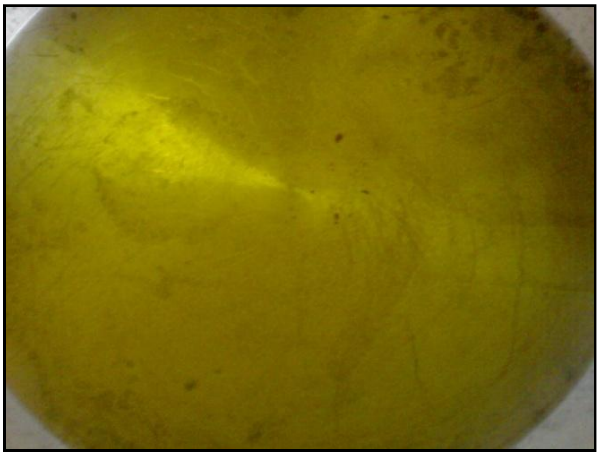


Plate 5.3.1.5: GNO color after 25 h of intermittent french fries frying

5.3.2: Intermittent frying stability of CSO and GNO used for frying bhajias in terms of its breakdown products

A. Chemical parameters

I. Peroxide value (PV)

Figure 5.3.2.1 shows the PV of GNO and CSO at different intervals of intermittent frying. Primary oxidation in cottonseed oil showed significant higher ($p<0.001$) values when compared with suggested limit i.e. <10meq O_2/kg than groundnut oil at 0 h (Ranganna S, 2003).

Upon frying the bhajias in CSO and GNO a significant ($p<0.001$) increase in PV was seen in both the oils at the end of 25 h of intermittent frying. PV of CSO decreased by 25% at the end of frying duration. GNO showed a progressive increase by 13% in PV up to 25 h of intermittent frying. No significant difference in PV value of both the oils was obtained at 10 h of intermittent frying (Appendix 11.4b).

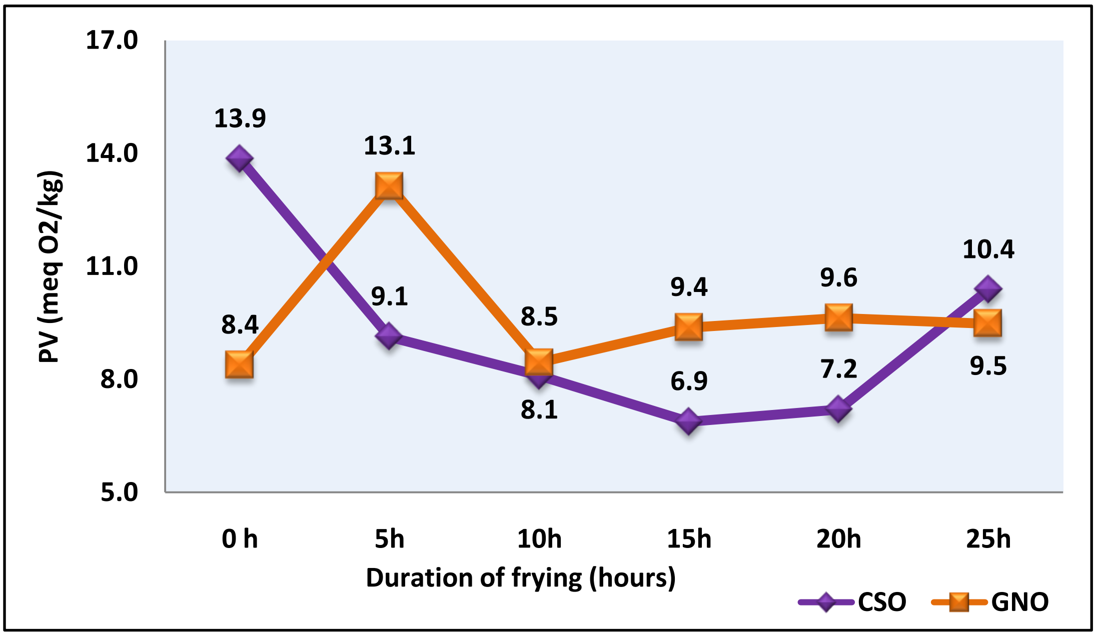


Figure 5.3.2.1: Peroxide value of GNO and CSO at intermittent frying intervals

Little correlation was observed between PV and duration of frying for both the oils (Figure 5.3.2.2).

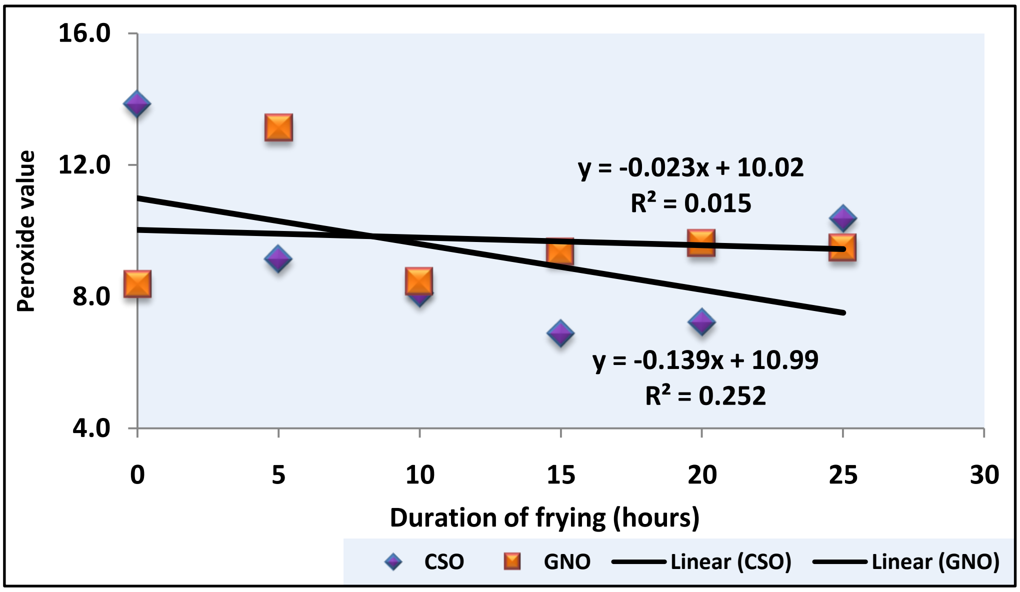


Figure 5.3.2.2: Relation between peroxide value and duration of frying

II. p-anisidine value (p-AV)

The secondary decomposition products assessed by p-AV are shown in Figure 5.3.2.3 and presented in Appendix (11.4b). At 0 h the p-AV of GNO and CSO was 0.58 and 8.71 respectively. However, CSO p-AV at 0 h was beyond the prescribed limit of 2 (Bhattacharya AB et al, 2008).

p-AV of CSO showed significant ($p<0.001$) increase from 62.09 to 85.47 at 5 and 10 h of intermittent frying of bhajias. GNO p-AV increased significantly ($p<0.001$) from 61.53 to 82.64 at 5 h and 10 h of bhajias frying. Increase in p-AV was continued to 25 h of intermittent frying duration of bhajias. Peroxide and p-anisidine values of CSO showed a negative correlation of r=-0.72 and GNO showed no relation r=0.08.

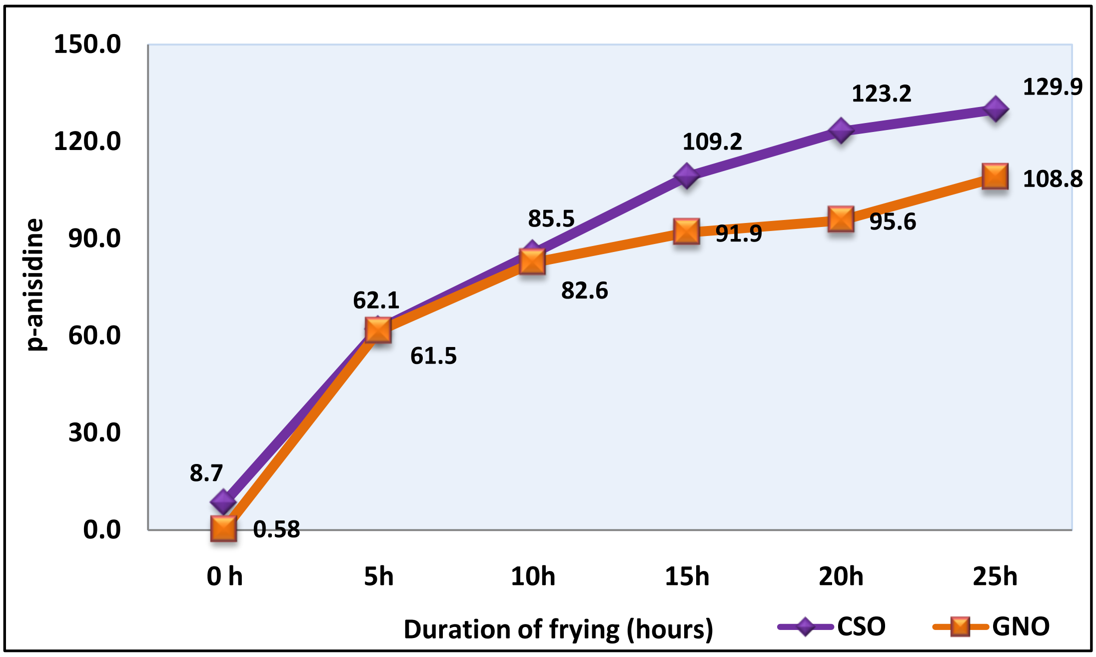


Figure 5.3.2.3: p-anisidine value of GNO and CSO at different frying intervals

As shown in Figure 5.3.2.4, p-anisidine value of CSO and GNO showed a strong linear relation with frying duration of bhajias.

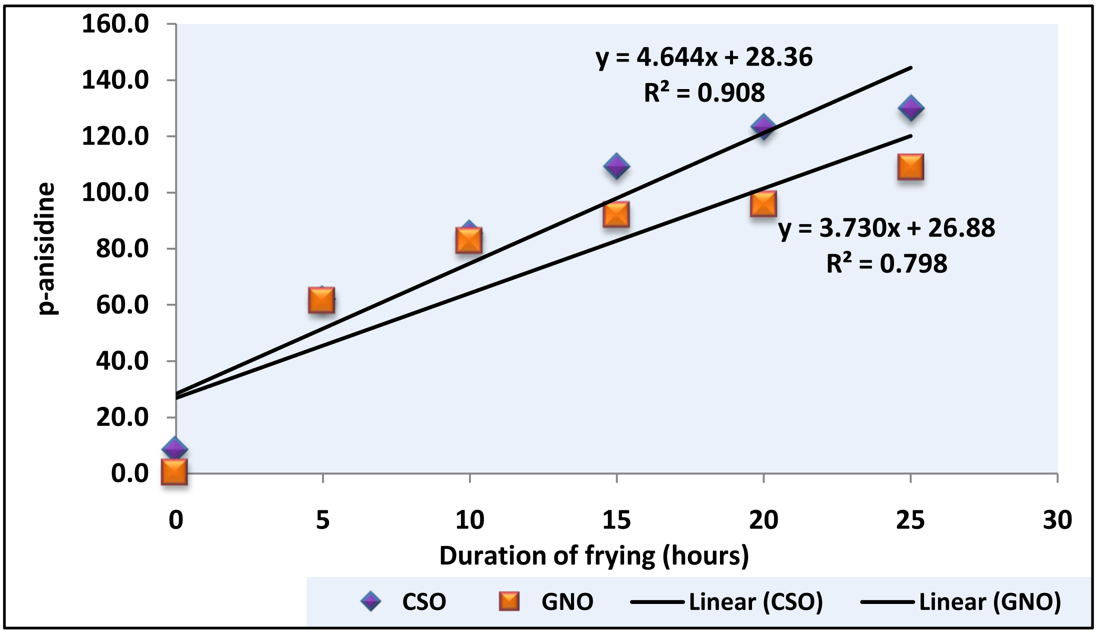


Figure 5.3.2.4: Relation between p-anisidine value and duration of frying

III. Totox value (TV)

The total oxidation products (TV) were significantly (p<0.001) formed in both the oils as the duration of bhajias frying increased (Table 5.3.2.1).

Table 5.3.2.1: Totox value of GNO and CSO at intermittent intervals of bhajias frying

Duration of frying (hours)	Totox value	
	GNO	CSO
0 h	17.3±0.4[a]	36.4±0.9[a]
5 h	87.8±3.6[b]	80.3±1.2[b]
10 h	99.5±3[c]	101.7±3.5[c]
15 h	110.6±0.8[d]	122.9±2.3[d]
20 h	114.8±1.8[e]	137.6±3.4[e]
25 h	127.7±2[f]	150.6±4.3[f]
F-value	**1199.02*****	**824.5*****

Note: *-significant at p<0.001; The superscripts with similar alphabets in each row indicate no significant difference between the values**

IV. Iodine value (IV)

The standard limit for IV of GNO and CSO is between 85 to 99 and 98 to 112 respectively (VOPO, 1998). The IV of CSO was significantly (p<0.05) altered after 25 h of intermittent frying, indicating decrease in unsaturated fatty acids shown in Table 5.3.2.2. However, bhajias fried in GNO showed no significant change at 25 h of intermittent frying.

Table 5.3.2.2: Iodine value (mg I_2/g of oil) of GNO and CSO at intermittent intervals of bhajias frying

Duration of frying (hours)	Iodine value	
	GNO	CSO
0 h	82.96±0.51	98.76±0.16[a]
5 h	85.75±4.65	101.34±4.19[a]
10 h	87.32±0.74	100.89±4.86[a]
15 h	87.7±1.06	99.21±3.10[a]
20 h	85.85±4.95	104.99±0.66[ab]
25 h	83.03±5.03	104.3±1.57[ab]
F-value	**1.37[NS]**	**2.96***

Note: *-significant at p<0.05; NS- not significant; The superscripts with similar alphabets in each row indicate no significant difference between the values

IV of GNO showed no relation with frying duration of Bhajias. However, regression equation showed a good relation (r^2=0.58) between IV of CSO and frying duration (Figure 5.3.2.5).

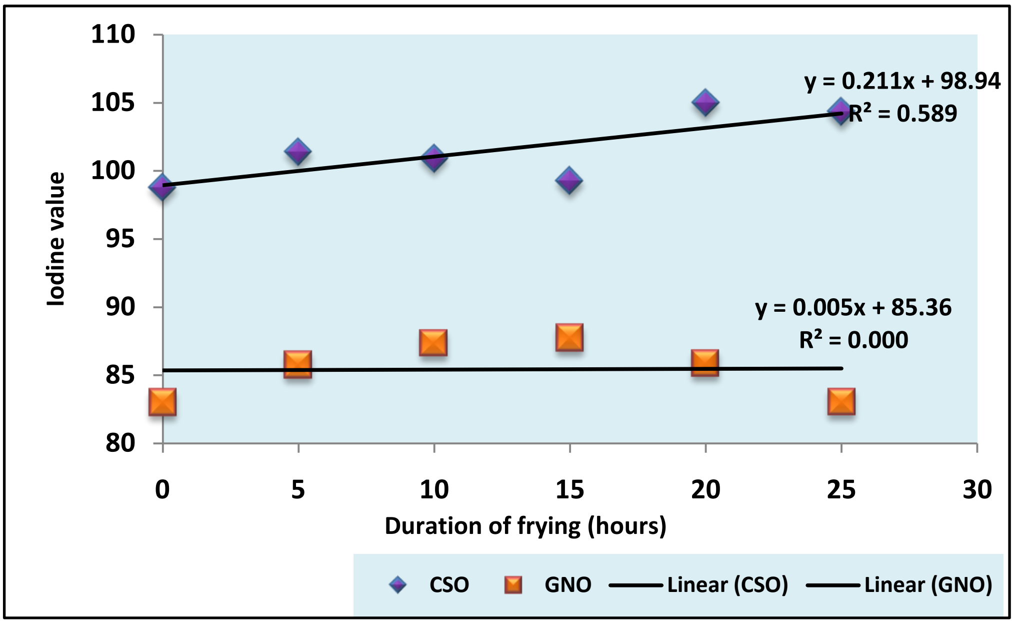


Figure 5.3.2.5: Relation between iodine value and duration of frying

V. Acid value (AV)

AV is popularly used for assessing the degradation of oils. Vegetable oil products order, 1998 suggested, AV for GNO and CSO was <6 mg KOH/g and 0.5 mg KOH/g of sample respectively. Acid value of GNO oil at 0 h was significantly ($p<0.001$) high because of different grades viz. filtered (GNO) and refined (CSO). As seen in Table 5.3.2.3, the AV continued to increase in both CSO as well as in GNO significantly ($p<0.001$) up to 25 h of frying. However, these values of both the oils were well in the acceptable limits.

Table 5.3.2.3: Acid value (mg KOH/g of sample) of GNO and CSO at intermittent intervals of bhajias frying

Duration of frying (hours)	Acid value GNO	Acid value CSO
0 h	0.78±0.07[a]	0.12±0.02[a]
5 h	0.85±0.04[a]	0.15±0.01[b]
10 h	0.97±0.01[b]	0.18±0.01[c]
15 h	1.04±0.02[c]	0.26±0.02[d]
20 h	1.22±0.5[d]	0.35±0.01[e]
25 h	1.29±0.06[d]	0.47±0.03[f]
F-value	**74.87*** **	**207.68*** **

Note: *-significant at p<0.001; The superscripts with dissimilar alphabets in each row indicate significant difference between the values**

Regression equation showed a strong positive relation of AV with intermittent frying (25 h) duration of GNO and CSO (Figure 5.3.2.6).

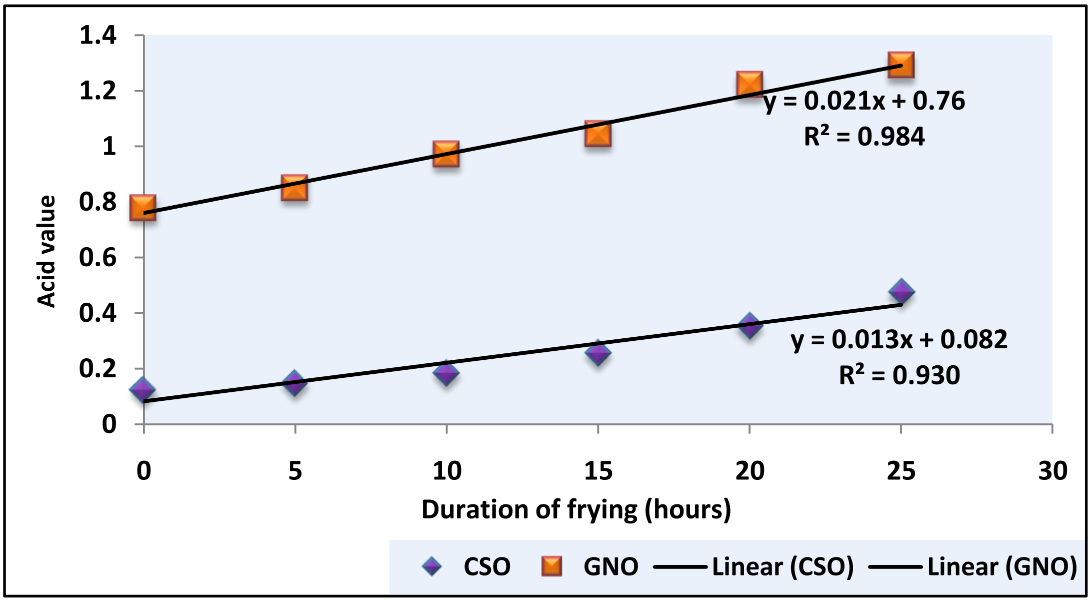


Figure 5.3.2.6: Relation between acid value and duration of frying

VI. Total polar components (TPC)

The results shown in Figure 5.3.2.6 showed that the contents of TPC increased almost linearly with the frying time. The initial TPC of GNO and CSO was 3.12 and 4, respectively, which was significantly ($p<0.001$) increased to 7.58 in GNO and 14.38 in CSO, at 25 h of intermittent frying.

The TPC of both the oils did not cross the limit of 25% as stated by European countries (Xu Xin-Qing, 1999). Student 't' test showed significant ($p<0.001$) difference amongst the TPC values of GNO and CSO (Appendix 11.4b).

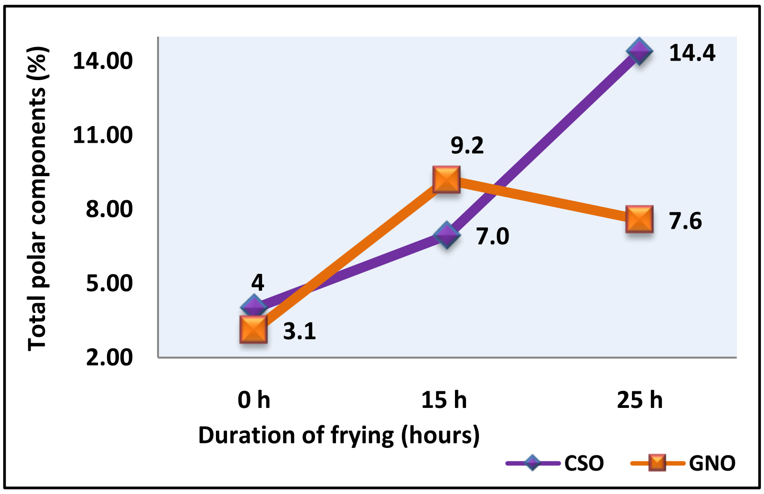


Figure 5.3.2.6: Total polar components (TPC) (%) of GNO and CSO at intermittent frying intervals

Figure 5.3.2.7 shows a strong positive correlation between TPC of CSO and GNO with duration of frying.

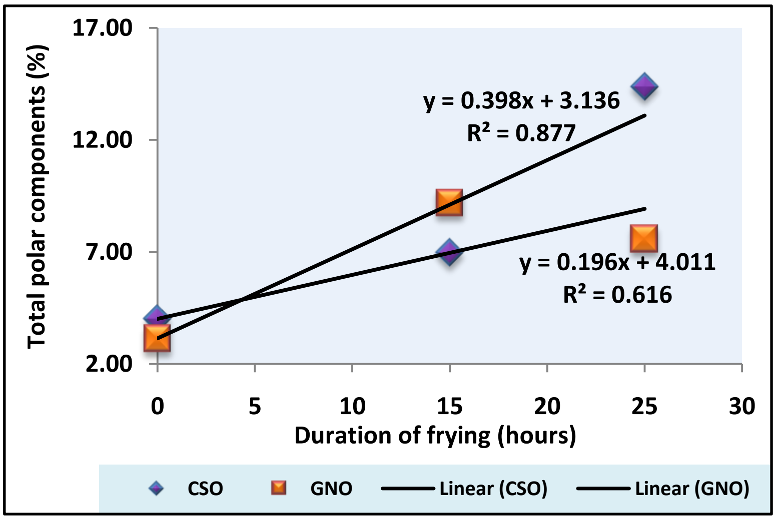


Figure 5.3.2.7: Relation between total polar components and duration of frying

VII. Fatty acid profile

Fatty acid profile of fried CSO and GNO are shown in Table 5.3.2.4. The saturated fatty acid content of GNO increased significantly ($p<0.05$) with the increase in frying hours. Palmitic acid was increased up to 6.21% and 6.8% in CSO and GNO respectively. 4.26% increase in stearic acid was observed in GNO at 25 h of intermittent frying. However, stearic acid in CSO did not significantly change. GNO rich in oleic acid (18:1) showed a significant ($p<0.001$) reduction of 1% at the end of frying duration. However, in CSO it showed a significant increase of 3.58%. Significant ($p<0.05$) decrease in polyunsaturated fatty acid (linoleic acid) of CSO was observed with increase in frying duration. The linolenic fatty acid of CSO was not significantly changed while the linolenic fatty acid of GNO was not detected at 15 and 25 h of intermittent frying. The linoleic acid to palmitic acid ratio (18:2/16:0) decreased significantly ($p<0.01$) in CSO whereas GNO 18:2/16:0 ratio showed no significant reduction during 25 h intermittent frying.

Fatty acid profile chromatograms of bhajias fried GNO and CSO at 0 and 25 h are shown in Plate 5.3.2.1.

Table 5.3.2.4: Fatty acid profile (g/100 g fat) of cottonseed oil (CSO) and groundnut oil (GNO) at intermittent intervals of bhajias frying

Fatty Acids		Frying Time (hours)			F-value
		0 h	15 h	25 h	
16:0 (Palmitic)	CSO	23.81±0.45	24.99±0.05	25.29±0.56	**7.02^{NS}**
	GNO	9.64±0.04^{a}	10.34±0.25^{b}	10.3±0.14^{b}	**10.71***
16:1 (Palmitoleic)	CSO	0.59±0	0.62±0.02	0.6±0.01	**1.46^{NS}**
	GNO	0.08±0.01	0.07±0.02	0.08±0.0	**0.7^{NS}**
18:0 (Stearic)	CSO	2.58±0.11	3.03±0.01	2.98±0.04	**4.02^{NS}**
	GNO	3.05±0.01^{a}	3.2±0.03^{bc}	3.18±0.01^{bc}	**33.17****
18:1 (Oleic)	CSO	18.7±0.10^{a}	19.3±0.27^{a}	19.37±0.02^{b}	**9.78***
	GNO	59.12±0.53^{a}	59.96±0.06^{a}	58.5±0.28^{ab}	**8.85***
18:2 (Linoleic)	CSO	50.76±0.07^{a}	48.81±0.07^{b}	49.5±0.65^{b}	**13.54***
	GNO	22.79±0.70	20.31±1.07	19.85±2.02	**2.63^{NS}**
18:3 (Linolenic)	CSO	0.33±0	0.36±0.02	0.36±0.04	**0.68^{NS}**
	GNO	0.21±0.02	-	-	**-**
18:2/16:0	CSO	2.13±0.04^{a}	1.95±0.0^{b}	1.96±0.02^{b}	**36.27****
	GNO	2.36±0.08	1.97±0.15	1.93±0.22	**4.40^{NS}**

Note: *-Significant at p<0.05, **- Significant at p<0.01, *- Significant at p<0.001, NS- not significant, ND-not detected; Mean ± SD followed by the same superscript in each row are not significantly different**

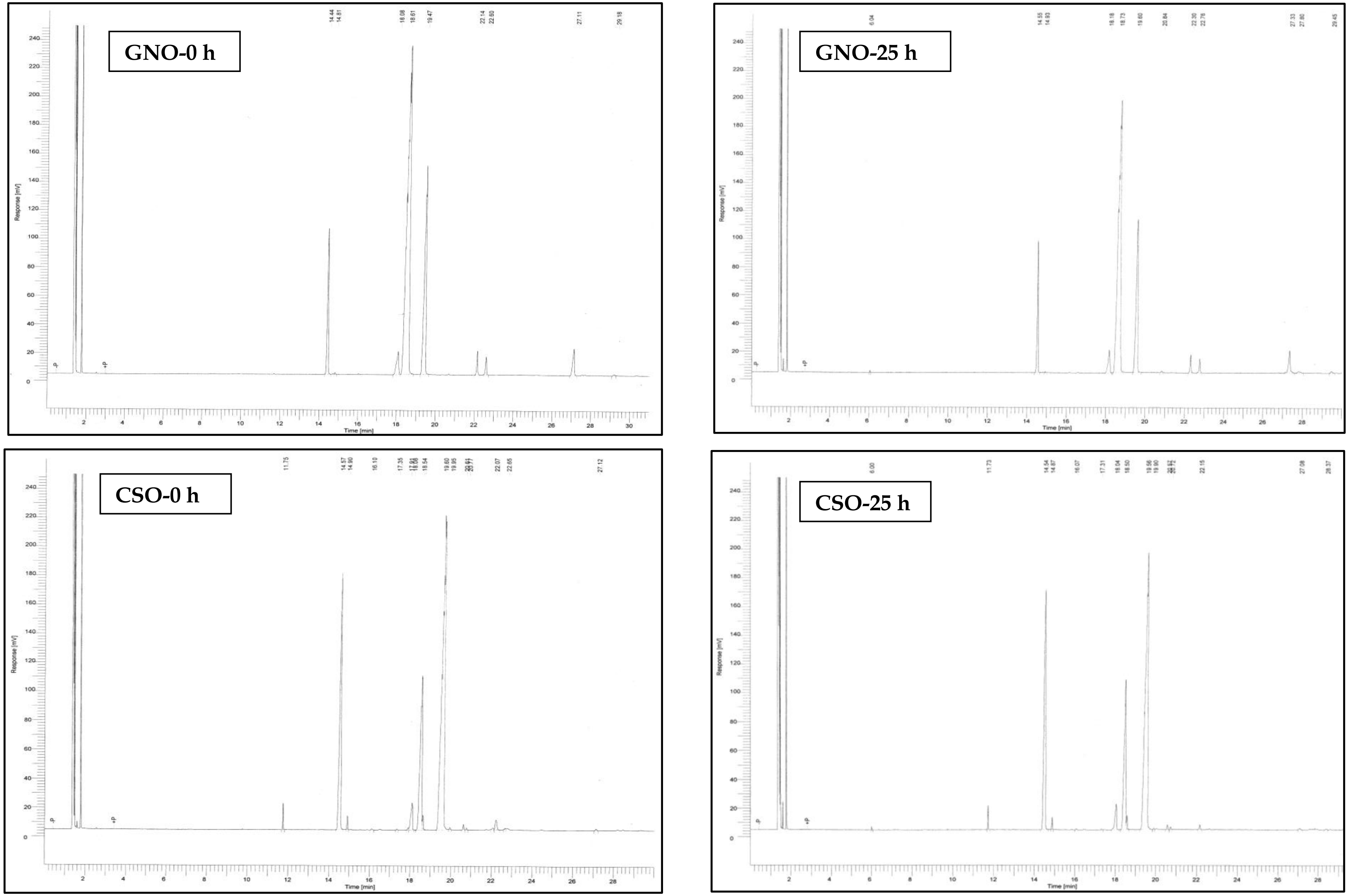


Plate 5.3.2.1: Bhajias fried GNO and CSO fatty acid profile chromatograms obtained at 0 and 25 h of intermittent frying

B. Physical parameters

I. Refractive Index (RI)

The RI and its relation with frying duration are presented in Figure 5.3.2.8 and 5.3.2.9. The refractive index of both the oils increased significantly ($p<0.001$) at the end of 25 h bhajias frying. However, both oils were within the recommended limit at 25 h of intermittent frying duration (GNO-1.4620-1.4640 and CSO-1.4630-1.4660). A strong positive relation of CSO and GNO with the duration of frying was observed.

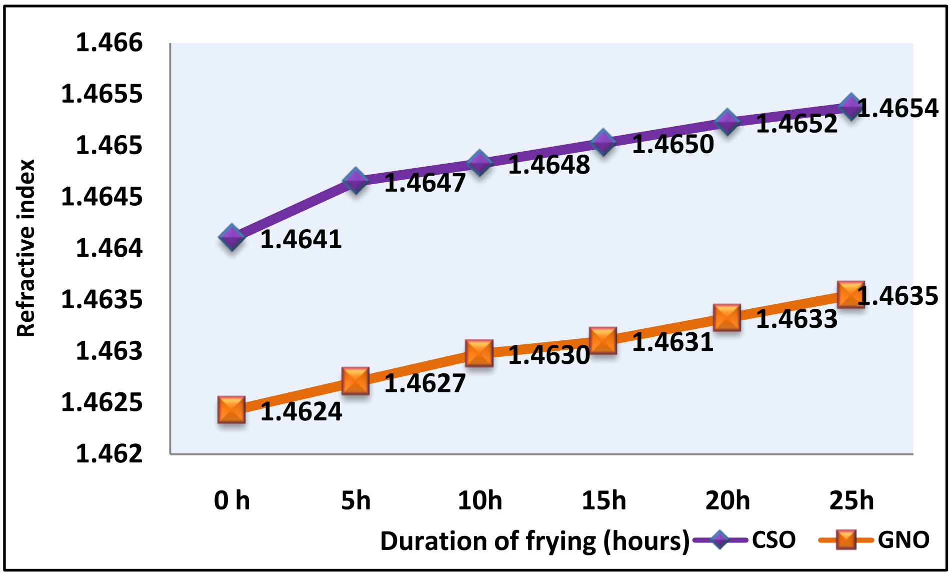


Figure 5.3.2.8: Refractive index of GNO and CSO at intermittent frying intervals

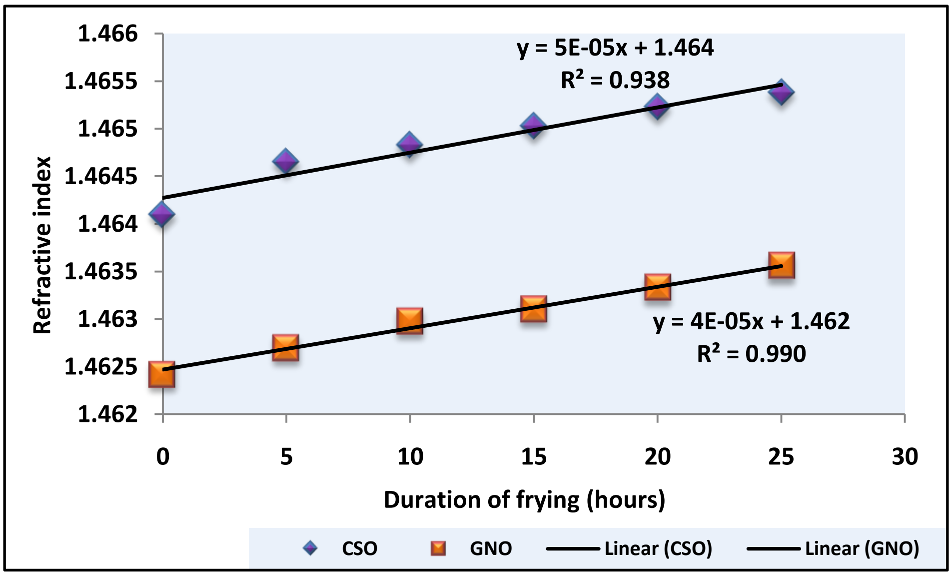


Figure 5.3.2.9: Relation between refractive index and duration of frying

II. Color

Change in color of fried oil is shown in Table 5.3.2.5. ANOVA analysis showed significant ($p<0.001$) increase in color of both the oils at the end of 25 h of intermittent frying. Significant increase ($p<0.05$) was observed in both yellow (Y) and red (R) color of bhajias fried in CSO and GNO at 5 h of intermittent frying. Increase in color of both the oils was noticed up to 25 h of intermittent frying.

Change in color of CSO and GNO used for bhajias frying is shown in Plate 5.3.2.2 and 5.3.2.3.

Table 5.3.2.5: Change in color of GNO and CSO at intermittent intervals of bhajias frying

Duration of frying (hours)	GNO		CSO	
	Y	R	Y	R
0 h	3.4±0.08^{a}	1.88±0.25^{a}	2.18±0.24^{a}	1.63±0.25^{a}
5 h	4.03±0.40^{b}	4.53±1.68^{b}	3.91±0.12^{b}	2.50±1.0^{ab}
10 h	4.53±0.13^{c}	5.58±0.05^{b}	6.03±0.51^{c}	3.25±0.29^{b}
15 h	5.30±0.24^{d}	5.55±0.1^{b}	7.03±0.64^{cd}	5.00±0.0^{c}
20 h	6.98±0.35^{e}	5..83±0.10^{bc}	7.55±0.70^{d}	6.38±1.44^{c}
25 h	7.85±0.37^{f}	7.3±0.22^{d}	9.13±0.19^{e}	14.25±2.87^{d}
F-value	**144.06*** **	**25.73*** **	**120.95*** **	**44.67*** **

Note: *-significant at p<0.05, **- significant at p<0.01, *- significant at p<0.001; Mean ± SD followed by the same superscript in each row are not significantly different**

Before After

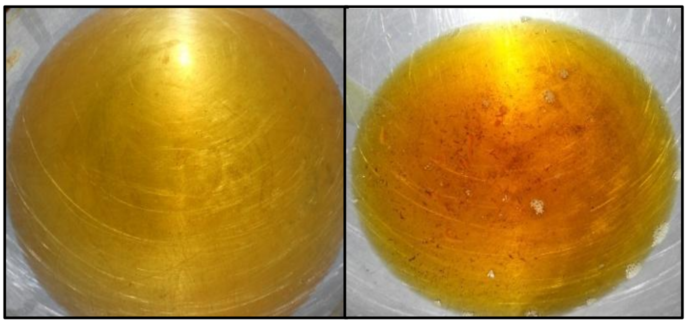


Plate 5.3.2.2: CSO color before and after 25 h of intermittent bhajias frying

Before After

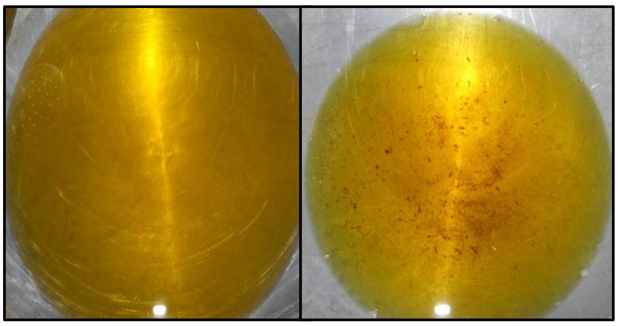


Plate 5.3.2.3: GNO color before and after 25 h of intermittent bhajias frying

5.3.3: Correlation of french fries and bhajias sensory attributes with chemical parameters of french fries and bhajias fried CSO and GNO

Products fried in oil for longer duration showed changes in their sensory and chemical quality of oil. The correlation coefficient of sensory attributes with chemical parameters is shown in Table 5.3.3.1.

A strong negative correlation in overall acceptability of french fries fried in GNO with different chemical parameters viz. peroxide value (r-0.80), p-anisidine (r-0.95) and acid value (r-0.89) was seen. However, iodine value showed a strong positive correlation (r 0.97) with overall acceptability (OA) of french fries fried in GNO. Whereas a negative correlation was seen in OA of CSO fried fries with peroxide (r-0.23), p-anisidine (r-0.29) and acid value (r-0.63). Overall acceptability of french fries in GNO was better correlated with chemical parameters than the OA of CSO. When odor, flavor and taste of french fries were correlated with the chemical parameters of CSO and GNO it was found that peroxide value, p-anisidine and acid value were have strong negative relation. Conversely, the iodine value of CSO and GNO was positively related with the odor and taste of french fries prepared in these oils. Greasiness scores of french fries prepared in CSO showed a strong negative correlation with p-anisidine and acid value (r-0.72 and r-0.89). GNO fried french fries greasiness scores also showed a strong negative correlation with the chemical parameters shown in table 5.3.3.1. However, iodine value of CSO and GNO revealed a strong positive correlation (r 0.81 and 0.94) with greasiness scores. Crispness of french fries showed a similar negative correlation with peroxide, p-anisidine and acid value of both the oils and iodine value showed positive relation with crispness scores of french fries.

Table 5.3.3.1: Correlation coefficient of sensory attributes with chemical parameters of french fries fried in CSO and GNO

Sensory attribute-chemical analysis	Type of oil	
	CSO	GNO
Overall acceptability	***Correlation coefficient (r)**	
Overall acceptability- peroxide value	-0.23	-0.80
Overall acceptability-p-anisidine	-0.29	-0.95
Overall acceptability-acid value	-0.63	-0.89
Overall acceptability-iodine value	0.48	0.97
Odor		
Odor- peroxide value	-0.24	-0.52
Odor- p-anisidine	-0.69	-0.92
Odor- acid value	-0.94	-0.97
Odor- iodine value	0.84	0.91
Flavor		
Flavor- peroxide value	-0.43	-0.87
Flavor- p-anisidine	-0.53	-0.94
Flavor- acid value	-0.75	-0.84
Flavor- iodine value	0.64	-0.93
Taste		
Taste- peroxide value	-0.12	-0.87
Taste- p-anisidine	-0.28	-0.86
Taste- acid value	-0.6	-0.70
Taste- iodine value	0.44	0.83
Greasiness		
Greasiness - peroxide value	-0.36	-0.59
Greasiness - p-anisidine	-0.72	-0.93
Greasiness - acid value	-0.89	-0.94
Greasiness - iodine value	0.81	0.94
Crispness		
Crispness - peroxide value	-0.16	-0.56
Crispness - p-anisidine	-0.45	-0.79
Crispness - acid value	-0.74	-0.70
Crispness - iodine value	0.60	0.78

Note-*-significant at $p<0.05$

The correlation coefficient of sensory attributes with chemical parameters is shown in Table 5.3.3.2.

Correlation of bhajias overall acceptability fried in GNO with different chemical parameters was r=0.57 (peroxide value), r=0.31 (p-anisidine) and r-0.43 (acid value). Iodine value showed negative correlation (r -0.06) with overall acceptability of bhajias fried in GNO and CSO. Bhajias fried in CSO was better correlated with chemical parameters than the overall acceptability of GNO. When scores of bhajias for odor, flavor and taste were correlated with the chemical parameters of CSO it was found that peroxide value was not well correlated, p-anisidine showed a strong negative relation with taste of CSO fried bhajias. Acid value of CSO showed a strong negative relation with flavor (r-0.78) and odor (r-0.76) scores of bhajias. Conversely, the correlation values of GNO with flavor and taste was not related.

When greasiness scores of bhajias was correlated with p-anisidine and acid value both CSO and GNO showed a strong negative relation. Crispness of GNO fried bhajias was positively correlated with p-anisidine, and acid value. However, crispness scores of CSO bhajias were positively associated with acid and iodine value except peroxide value.

Table 5.3.3.2: Correlation coefficient of sensory attributes with chemical parameters of bhajias fried in CSO and GNO

Sensory attribute-chemical analysis	Type of oil	
	CSO	GNO
Overall acceptability	***Correlation coefficient (r)**	
Overall acceptability- peroxide value	0.35	0.57
Overall acceptability-p-anisidine	-0.54	0.31
Overall acceptability-acid value	-0.76	0.43
Overall acceptability-iodine value	-0.18	-0.06
Odor		
Odor- peroxide value	0.48	0.78
Odor- p-anisidine	-0.64	0.26
Odor- acid value	-0.76	0.21
Odor- iodine value	-0.81	-0.01
Flavor		
Flavor- peroxide value	0.42	0.78
Flavor- p-anisidine	-0.60	0.17
Flavor- acid value	-0.78	0.11
Flavor- iodine value	-0.21	-0.07
Taste		
Taste- peroxide value	0.59	0.57
Taste- p-anisidine	-0.75	0.01
Taste- acid value	-0.88	0.15
Taste- iodine value	-0.35	-0.33
Greasiness		
Greasiness - peroxide value	0.63	0.53
Greasiness - p-anisidine	-0.66	-0.66
Greasiness - acid value	-0.54	-0.75
Greasiness - iodine value	0.11	-0.64
Crispness		
Crispness - peroxide value	-0.22	0.03
Crispness - p-anisidine	0.38	0.61
Crispness - acid value	0.60	0.58
Crispness - iodine value	0.94	0.40

Note-*significant at $p<0.05$

PHASE III - RESULT HIGHLIGHTS

French fries

- *Significant increase ($p<0.05$) in various chemical parameters of CSO and GNO was observed as a result of intermittent frying of french fries up to 25 h.*
- *In terms of oxidation products i.e. peroxide value (PV), p-anisidine value (p-AV) and total oxidation products (Totox value-TV), CSO showed significant increase ($p<0.001$) than GNO during 25 h of intermittent frying.*
- *Iodine value (IV) of both the studied oils decreased significantly ($p<0.01$) with frying hours and a strong relation was observed between the duration of frying and IV of oils.*
- *French fries frying result in significant increase ($p<0.01$) in acid value (AV) of CSO and GNO during 25 h of intermittent frying. A strong relation was observed between duration of frying and AV.*
- *With regard to total polar components (TPC) increase from 1.9% and 1.1% to 11.5% and 10.6% was observed in CSO and GNO respectively at the end of frying duration. However, this increase in TPC of CSO and GNO was within the standard limit (<25%) set by European countries.*
- *Palmitic acid increased significantly ($p<0.01$) up to 16.4% and 11.8% in CSO and GNO respectively at the end of 25 h intermittent frying.*
- *Linolenic acid in GNO was totally missing with increased frying time (15 h). However, linolenic acid in CSO decreased significantly ($p<0.01$) up to 25 h of intermittent frying.*
- *18:2/16:0 ratio of GNO and CSO decreased by 33.8% and 25% respectively at the end of 25 h intermittent frying.*
- *Color and refractive index of CSO and GNO increased significantly ($p<0.001$) with the increase in frying duration.*

Bhajias

- *Significant increase ($p<0.001$) was observed in oxidation parameters (PV, p-AV and TV) of CSO and GNO* when *bhajias were fried intermittently up to 25 h.*
- *Bhajias fried in CSO showed significantly higher ($p<0.05$) values for PV, p-AV and TV than GNO during 25 h of intermittent frying. No correlation was found between PV and duration of frying.*
- *The IV of CSO was significantly ($p<0.05$) altered after 25 h of intermittent frying, indicating decrease in unsaturated fatty acids.*
- *The AV continued to increase in both CSO as well as in GNO significantly ($p<0.001$) up to 25 h of frying. Strong correlation was found between AV and duration of frying.*
- *TPC of CSO and GNO increased significant ($p<0.001$) at 25 h of intermittent frying.*
- *Saturated fatty acids (palmitic and stearic acid) of CSO did not increase when bhajias were fried intermittently up to 25 h. However, saturated fatty acids of GNO increased significantly.*
- *Oleic acid of CSO and GNO increased significantly ($p<0.05$) when bhajias were fried for 15 h intermittently.*
- *18:2/16:0 ratio of CSO decreased significantly ($p<0.01$) by 7% during 25 h of intermittent frying. Non significant decrease in 18:2/16:0 ratio was observed in GNO.*
- *Refractive index and color of bhajias fried oils increased as frying duration increased.*

DISCUSSION

In India, deep-fat-fried products form the major route through which oils and fats are consumed (Narasimhamurthy K and Raina PL, 1998). Deep fat frying is one of the oldest processes of food preparation and consists basically in the immersion of food pieces in hot oil. During frying, fat is subjected to hydrolysis, oxidation and polymerization that result in quality deterioration with respect to quality and nutritive quality of oil. The mechanisms of such processes are essentially the same in different fats; the rates at which different fats undergo deteriorative reactions vary. The choice of frying fat depends on many factors, such as availability, price, frying performance, and flavor. Frying oil acts as a heat transfer medium and contributes to the texture and flavor of fried foods (Choe E and Min DB, 2005).

Vegetable oil quality and stability are the main factors that influence consumer acceptability, market value and its health implications. Usually many oils can be used for frying e.g. palm oil, corn oil, cottonseed oil, soya oil, groundnut oil, sunflower oil etc.

Deep fat frying is normally carried out at high temperatures (between 160 and 180^0C) and in the presence of air and moisture, these frying oils and fats may undergo physical and chemical deteriorations that may affect the frying performance and stability of fried products (Choe E and Min DB, 2005). The most appropriate frying oil should be low in free fatty acids and polar compounds.

Deep fried foods are important food items in the diet and are widely available at street level from vendors. The necessity of using a good quality frying medium become obvious when one considered that some of the fat is absorbed by every piece of food fried in it. The overuse of deep-fried oil for frying may cause adverse effects on flavor, stability, color and texture of fried product and may be harmful to human health (Sulieman AERM, Makhzangy AE and Ramdan MF, 2006).

Several studies have been carried out to see the physico-chemical and sensory changes taking place in oil for prolonged frying hours (Xu Xin-Qing, 1999; Ryan LC et al, 2008; Warner K, Neff WE and Eller FJ, 2003; Warner K and Fher W, 2008).

Preliminary study regarding the frying practices in the households of Gujarat revealed that the Gujarati housewives do not deep fry the products for great length of time as reported by many studies. And therefore our study is focused on physico-chemical changes take place in deep fried oils and the sensory changes in the products fried in such oils for a shorter duration of frying time (total of 2.5 h /25 h of intermittent frying).

In the present study, CSO used for frying french fries and bhajias both, CSO showed less stability in terms of PV than GNO because oil containing higher amount of polyunsaturated fatty acids are more susceptible to oxidation than oils with higher monounsaturated fatty acids. Higher formation of peroxides in PUFA rich oils may be due to the lower activation energy, required by them in the initiation of free-radical formation (Tyagi VK and Vasistha AK, 1996).

PV of various oils have shown to vary during intermittent frying, study by Sulieman AERM, Makhzangy AE and Ramdan MF, 2006 showed that PV of cottonseed oil (1.9-33) was more than sunflower (1.7-28) and palm olein (1.6-10) when French fries were fried for 16 h of intermittent frying, indicating a greater extent of oxidation in cottonseed oil. Another study on comparative analysis of four vegetable oils namely mustard, groundnut, soybean and safflower oil revealed when potato chips were fried, PV increased maximum in the last two PUFA rich oils than MUFA rich oils (mustard and groundnut oil) (Sharma R et al, 2007).

In our study, bhajias fried in CSO and GNO shows less PV as compared to PV of respective oils used for frying french fries. Study conducted to observe the deterioration in oils used for frying different products showed, PV of frying medium used for frying cod fillets was 2 times lower than oils used for frying sliced potatoes (Tynek M et al, 2001). Refined and partially hydrogenated (PH) rapeseed oil (RSO) was subjected to frying potato fritters, PV of refined and PH RSO increased from 0.6 to 8.87 and 0.0 to 10.3 meqO_2/kg of oil respectively (Hazuka Z et al, 2000).

PV of a blend of refined cottonseed oil: mustard oil (80:20) increased from 9 to 38 meqO_2/kg when *pooris* were fried for 6 h of continuous frying. This increase in PV of oil may possibly due to greater contribution of PUFA (80%) in oil blend (Premavalli KS, Madhura CV and Arya SS, 1998).

In the present study, peroxide values of oils showed rise and fall as the duration of frying increased. This is indication of instability of peroxides is also reported by Rani AKS, Reddy SY and Chetana R, 2010. This was in accordance with Farhoosh R and Moosavi SMR (2009) who stated parallel results when various vegetable oils were used for frying. Augustin MA and Berry SK (1983) indicated that use of PV for following the oxidative deterioration of fats and oils during deep-frying is problematic because peroxides are destroyed by heating temperature and during cooling new peroxides are formed.

As the regression equations of PV in the present study, it has been stated that during frying the changes in PV were not related to duration of frying, but may be dependent on rate of formation and breakdown of oxidation procedure (Sulieman AERM, Makhzangy AE and Ramdan MF, 2006).

Increase in p-AV of oil used frying may perhaps be explained by lipid oxidation of oils which is due to formation of unsaturated aldehydes during frying. In present study, p-anisidine values of CSO were higher than GNO at all intermittent intervals of french fries and bhajias frying. This is because higher p-anisidine values of CSO rich in PUFA more prone to oxidation than GNO (MUFA). Similar findings have been reported by Ryan LC et al (2008), when sunflower, corn, and soybean oil (PUFA rich oils) fried discontinuously up to 96 h showed higher increment in p-AV as compared to peanut and olive oil (MUFA). Another study by Das AK et al (2011) reported significant increase in p-anisidine values of GNO from 8.99 to 172.4 during intermittent frying and increased from 8.99 to 133 at the end of continuous frying of *pooris*. Further, when potato fritters were fried in refined rapeseed oil for continuous 9 days (15 cycles each day), p-AV increased from 3.8 to 186 (Hazuka Z et al, 2000).

Difference in p-AV of oil used for frying french fries and bhajias has also been observed in the present study. Similarly, frying of cod fillets in rapeseed oil (RSO) showed smaller increase in p-AV as compared to RSO used for frying potato slices (Tynek M et al, 2001).

p-AV of CSO and GNO in the present study shows a strong relation with frying duration. Study on frying of rice flakes in crude red palm oil (CPO), and its blend with sunflower and groundnut oil showed increase in p-AV with increased heating and frying regimen (Goyal N and Sundararaj P, 2009). On the contrary when canola oil was used for frying at higher temperatures (215^0C) p-AV was not well correlated with duration of frying (Aladedunye FA and Przybylski R, 2009).

Intermittent frying results in progressive decrease in unsaturation of both the oils, whereas decrease in iodine value (IV) of CSO was much faster than GNO. Many researchers have shown similar results when soybean oil rich in unsaturated fatty acids was used as frying medium had faster loss of unsaturation than *vanaspati*, partially hydrogenated canola and palm olein oils (Tyagi VK and Vasistha AK, 1996; Xu XQ et al, 1999). It has been observed that thermal oxidation and degradation of oils, results decrease in unsaturated fatty acids content and hence rapid decrease in iodine value.

Both CSO and GNO showed a considerable decrease in IV when used for frying french fries and bhajias. However, the decrease was well within the suggested limits set by vegetable oil products order, 1998. Study by Baixauli R et al (2002) observed continuous decrease in IV of high oleic refined sunflower oil when batter coated squid rings were fried intermittently. Other studies have also reported decrease in IV of sunflower oil, *vanaspati*, bakery shortening and rapeseed oil used for frying *chiroti* (refined wheat flour made deep fried product) and french fries respectively (Rani AKS, Reddy SY and Chetana R, 2010; Kita A, Lisinska G and Powolny M, 2005).

The possible reason for reduction in IV of oil used for frying purposes may be due to removal of hydrogen adjacent to the double bond, oxidation, scission, and polymerization (Tyagi VK and Vasistha AK, 1996).

Acid value (AV) and total polar components (TPC) indicators of chemical deterioration of oil showed little changes in CSO and GNO when french fries and bhajias were intermittently fried for 25 h. Initial AV and TPC values of both the oils was in recommended limit set by Vegetable Oil Products Order (1998) and European countries.

In both french fries or bhajias frying, higher increase in AV was noticed in CSO at all frying intervals. A comparative study on frying stability of sunflower, mustard, groundnut oil showed more stability than *desi ghee* and *vanaspati* in terms of AV (Kaur A, Hira CK, and Raheja RK, 1997). It has been observed that AV of oil is affected by the type of frying oil and the type of food being fried (Melton SL et al, 1994).

In the present study, bhajias fried in CSO and GNO showed lesser AV than french fries fried oils. This may be due to presence of salt which cause additional denaturation of proteins, which may lead to the appearance of new junction points for the formation of bonds with COOH groups in the fatty acids (Llorca E et al, 2003). AV of the oils in our study increased significantly during frying and was strongly related with duration of frying, supporting similar trend of the previous studies (Xu Xin-Qing et al, 1999; Farag RS, Farag MM and Ali RFM, 2008). Although in each case it did not reach to the discarding limit (>2.5) set by EU (Xu Xin-Qing, 1999).

In the present study TPC was steadily increased in both the oils (CSO and GNO) with frying duration. Present results are in accordance with the other studies findings that TPC increase with the frying duration (Romero A, Cuesta C and Sanchez-Muniz FJ, 1998; Normand L, Eskin NAM and Pryzbylski R, 2001; Aladedunye FA and Pryzbylski R, 2009). This increase in

TPC may possibly be due to thermo oxidative alteration in oils during the experimental period of frying.

As TPC is a good indicator of frying oil quality, and frying oils with 25-27% TPC content have deteriorated to the point where they should be discarded (White PJ, 1991). To reach to the discarding limit (25%), Razali I and Badri M (2003) revealed, it took 3 days when frozen french fries were intermittently fried in palm oil, palm olein, soybean or hydrogenated oil at 180^{0}C for 4 minutes per batch for a total frying period of 8 hours a day, over 5 consecutive days.

Present findings showed, irrespective of the type of products fried, CSO had significantly higher TPC than GNO thus indicating less stability of PUFA. In 2002, Sanchez-Muniz FJ and Bastida S reported that during the initial 20 h of discontinuous frying operations polar components increased more intensively, mainly in sunflower oil than olive oil and their blend. In another study, when wheat flour dough containing egg yolk powder was repeatedly fried in sunflower oil it was found contents of polar compounds formation increased upon repetition of frying (Kim H and Choe E, 2008).

Change in fatty acid profile of oil during frying was observed in the present study also. As a result of frying many changes occurred because of cyclization, polymerization, pyrolytic, oxidative, hydrolytic and other chemical changes promoted by frying conditions (Tyagi VK and Vasistha AK, 1996).

Alteration in saturated fatty acids (SAFA) during frying was significant in both the oils irrespective of the products fried in them. Palmitic (C16:0), and stearic (C18:0) of CSO and GNO was increased in both the oils as the frying duration increased. Houhoula DM, Oreopoulou V and Tzia C (2002) showed increase in saturated fatty acids of refined cottonseed oil during 12 h of intermittent frying. Study by Aladedunye FA and Przybylski R (2009) showed similar results, during frying of canola oil at 185^{0}C.

Monounsaturated fatty acid (oleic acid; C18:1) concentration in CSO and GNO was increased when french fries were fried in the present study. This unusual increase in oleic acid was also observed by Sulieman AERM, Makhzangy AE and Ramdan MF, (2006); Toliwal SD and Tiwari MR (2008), explaining the migration of fatty acid from foods being fried into the oil could be the possible reason.

The results show generally that, in both (CSO and GNO) the frying mediums, there were decrease in polyunsaturated fatty acids (C18:2 and C18:3). Linoleic acid (C18:2) in both the oils decreased in considerable amount when french fries and bhajias were fried intermittently up to 25 h. Linolenic acid (C18:3) in GNO was totally missing at 15 and 25 h of french fries and bhajias frying. Similarly, Tyagi VK and Vasistha AK (1996); Aladedunye FA and Przybylski R, 2009 and Tynek M et al (2001) also reported losses in triene content (C18:3) was much higher than monoenes (C18:1) and dienes (C18:2). Polyunsaturated fatty acid (PUFA) rich oil degraded much faster because of lipid oxidation (Nzikou JM et al, 2009). This decrease in both the studied oils signifies that heat treatment of fats induces alteration of fatty acids with two or three double bonds. In the current study the level of PUFA tended to decrease, whereas that of SAFA increased.

Studies suggested decrease in linoleic acid to palmitic acid ratio (18:2/16:0) as a convincing indicator of PUFA deterioration (Houhoula DM, Oreopoulou V and Tzia C, 2002; Aladedunye FA and Przybylski R, 2009). Present study also showed a similar decrease in 18:2/16:0 ratio of CSO and GNO when french fries and bhajias were fried up to 25 of intermittent frying.

Physical parameters of the studied oils i.e. refractive index and color increased significantly with the frying time. Different studies showed increase in RI of oils after frying, auto and photo oxidation (Tyagi VK and Vasistha AK, 1996; Raza SA et al, 2009). Study showed similar pattern of increase in refractive index of oil, when *pooris* were fried in blend of cottonseed and mustard oil (Premavalli KS, Madhura CV and Arya SS, 1998).

Change in color of oil when french fries and bhajias were fried was a result of browning during frying, attributed half to the amino-carbonyl reaction between amino acids and carbonyl compounds generated from oil or presence of certain compounds could possibly be the other reason (Totani N et al, 2006; Narasimhamurthy K and Raina PL, 1998).

Our study had showed a significant increase in color of oil, this can be due to food fried had plenty water at ambient temperature are put in heated oil, numerous bubbles are formed, resulting in drastic oxidation of the oil due to great increases of oil surface (Totani N et al, 2007). In a study by Ogunsina BS et al in 2011 showed 52% increase in color intensity of refined groundnut oil when potato slices were fried in 10 repeated successions spanning a total time of 2 h. Rise in color intensity of fried oils is indicative of increase in its oxidation (redder the oil, the more oxidized it is) thus reducing its stability (Hack DM, Bordi PL and Hessert SW JR, 2009).

To conclude, thermal-oxidation of GNO and CSO was noticed at 5 h of intermittent frying as indicated by rise in PV and p-AV beyond the acceptable limits. In terms of acid value and iodine value, CSO showed less stability than GNO and crossed the standard limits. Considering deteriorative factor fatty acid profile in fried oils, linolenic acid went totally missing in GNO when french fries and bhajias were fried in it. Decrease in 18:2/16:0 ratio was greater in CSO than GNO when french fries and bhajias were intermittently fried for 25 h.

PHASE II

5.2: SENSORY QUALITIES OF FRENCH FRIES AND BHAJIAS FRIED IN COTTONSEED OIL (CSO) AND GROUNDNUT OIL (GNO) DURING INTERMITTENT FRYING

Fried foods have become more and more popular in spite of the present guidelines which recommend to decrease the level of fat in the diet. The main reason for this is that frying is a fast and convenient technique for production of foods with unique sensory properties of color, flavor, texture, and palatability, highly appreciated by consumers. The simultaneous heat and mass transfer of oil, food, and air during frying produces desirable and unique quality in the fried foods. These positive changes are accompanied by some undesirable modifications of the frying medium. It is very well known that, during deep-frying, thermal, oxidative, and hydrolytic reactions take place and, thus, physical and chemical changes in the oil or fat are expected to occur as a consequence of the formation of new compounds. These changes in turn may affect the sensory qualities of products fried in it.

In this phase of the study, sensory evaluation of french fries and bhajias was carried out at 0, 6, 11, 16 and 21 h of intermittent frying (Plate 5.2.1.1). 25 (Twenty five) semi-trained sensory panelists who were familiar with the quality of french fries and bhajias were selected as described in Methods and Material chapter 3. Freshly fried (hot) french fries and bhajias were judged for appearance, color, crispness, greasiness, flavor, taste, odor, and overall acceptability. French fries and bhajias were evaluated on 9-point hedonic scale for their organoleptic qualities. The results of this phase are presented under the following heads:

5.2.1: Sensory quality of french fries fried in CSO and GNO at intermittent durations.

5.2.2: Sensory quality of bhajias fried in CSO and GNO at intermittent durations.

5.2.3: Comparison of french fries (non-coated) and bhajias (batter coated) fried in CSO and GNO for difference in their sensory mean scores.

5.2.4: Oil uptake by french fries and bhajias fried in CSO and GNO at 25 h of intermittent frying.

5.2.1: Sensory quality of french fries fried in CSO and GNO at intermittent durations

Figure 5.2.1.1 shows the mean sensory scores of french fries for appearance, color, crispness and greasiness fried in CSO and GNO. F-test (ANOVA) showed no significant difference in mean sensory scores for appearance, color, and crispness of french fries fried in CSO and GNO during and at the end of 21 h intermittent frying period. However, crispness scores of CSO fried fries were significantly high ($p<0.05$) at 11 h as compared to GNO (Table 5.2.1.1).

Greasiness an important undesirable attribute in fried foods is significantly influenced by the quality of oil used, temperature, duration of frying, and type of product and its composition (Figure 5.2.1.1). In the present study, with the increase in intermittent frying period greasiness significantly increased ($p<0.05$) in french fries fried in CSO was observed as compared to GNO (Plate 5.2.1.2). However, no significant difference was observed between the greasiness scores of french fries fried in CSO and GNO (Table 5.2.1.1).

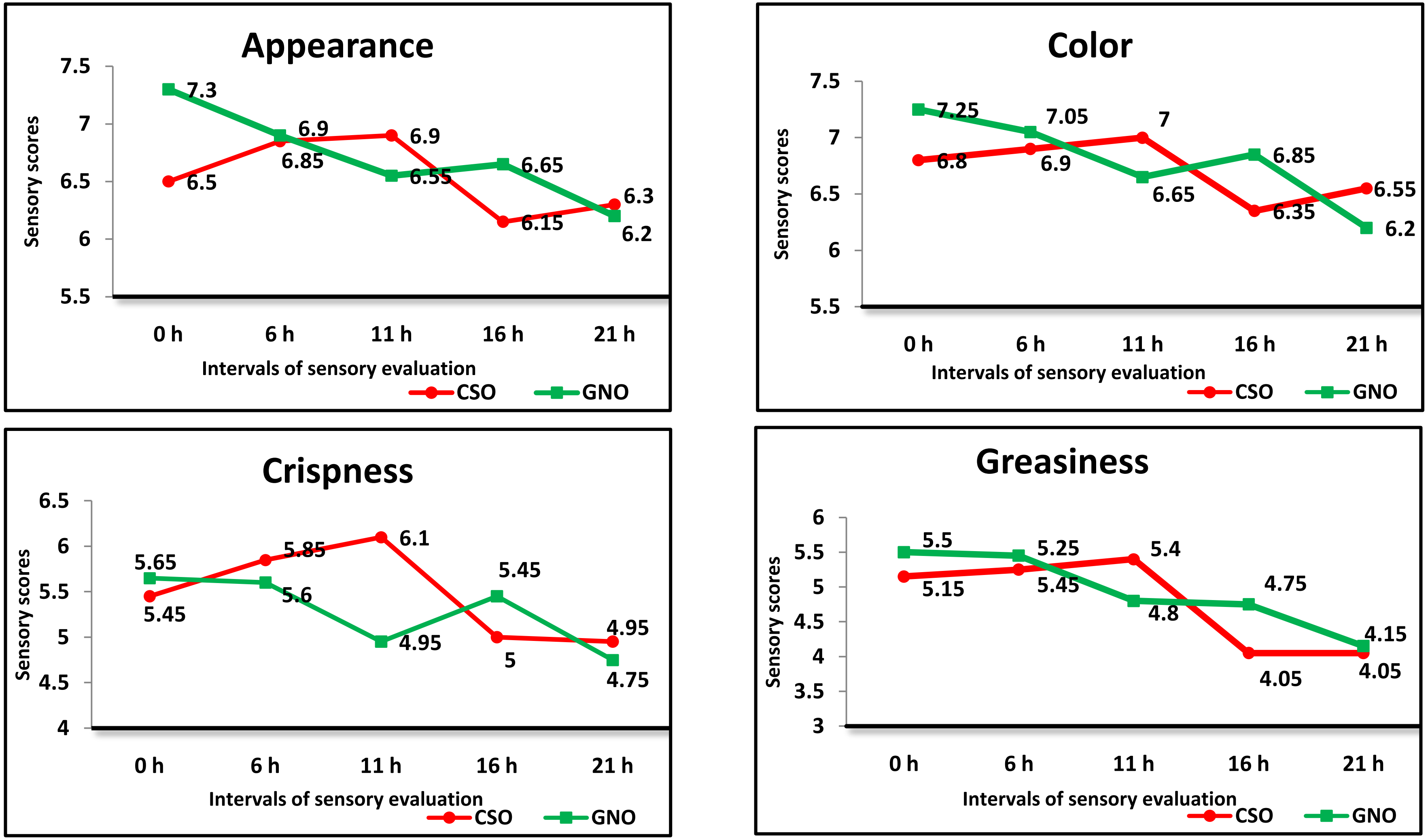


Figure 5.2.1.1: Mean sensory scores for appearance, color, crispness and greasiness of french fries fried in CSO and GNO at intermittent intervals

Plate 5.2.1.1: Panelists performing sensory evaluation

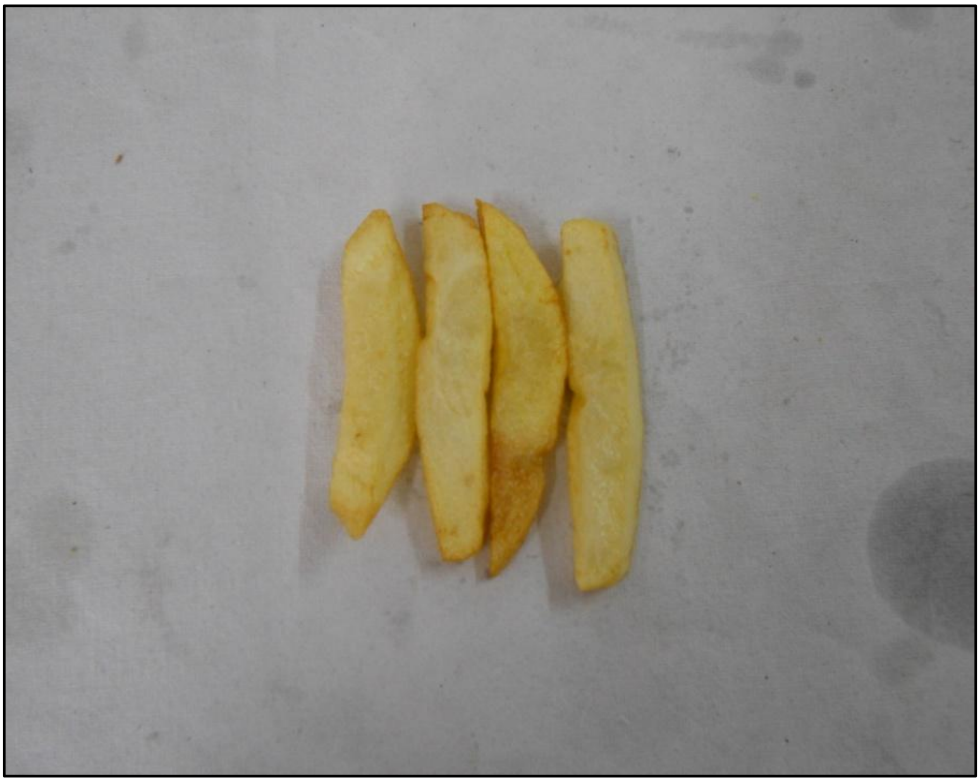


Plate 5.2.1.2: Puffiness/Absorption of oil in french fries at the end of 21 h of intermittent frying

Table 5.2.1.1: Mean sensory scores of french fries fried in CSO and GNO at intermittent duration of frying

Sensory Attributes	Oil	0 h	6 h	11 h	16 h	21 h	F-value
Appearance	CSO	6.5±1.4	6.8±1.1	6.9±0.85	6.1±1.4	6.3±1.2	**1.4**^{NS}
	GNO	7.3±1.1	6.9±1.2	6.5±1.4	6.6±0.93	6.2±1.4	**2.1**^{NS}
	't'	**1.99**^{NS}	**0.13**^{NS}	**0.94**^{NS}	**1.27**^{NS}	**0.24**^{NS}	
Color	CSO	6.8±1.4	6.9±0.97	7±0.92	6.3±1.3	6.5±1.1	**1.03**^{NS}
	GNO	7.2±1.0	7.0±1.0	6.6±1.5	6.8±0.93	6.2±1.3	**2.28** ^{NS}
	't'	**1.14**^{NS}	**0.5**^{NS}	**0.86**^{NS}	**1.39**^{NS}	**0.89**^{NS}	
Crispness	CSO	5.4±1.4	5.8±1.8	6.1±1.3	5±1.7	4.9±1.7	**1.91**^{NS}
	GNO	5.6±1.7	5.6±1.4	4.9±1.6	5.4±1.7	4.7±1.5	**1.21** ^{NS}
	't'	**0.39**^{NS}	**0.48**^{NS}	**2.41***	**0.80**^{NS}	**0.37**^{NS}	
Greasiness	CSO	5.1±1.4^{a}	5.2±1.5^{a}	5.4±1.6^{a}	4.0±1.7^{b}	4.0±1.6^{bc}	**3.59***
	GNO	5.5±1.8	5.4±1.3	4.8±1.5	4.7±1.5	4.1±1.7	**2.42** ^{NS}
	't'	**0.68**^{NS}	**0.44**^{NS}	**1.19**^{NS}	**1.36**^{NS}	**0.19**^{NS}	
Flavor	CSO	6.05±1.76^{a}	6.05±1.82^{a}	6.75±1.07^{ab}	5.2±2.09^{ac}	5.15±1.93^{ac}	**2.88***
	GNO	6.8±1.15^{a}	6.2±1.44^{ab}	5.6±2.01^{b}	5.9±1.33^{b}	5.45±1.39^{b}	**2.58***
	't'	**1.59** ^{NS}	**0.29** ^{NS}	**2.25***	**1.26** ^{NS}	**0.56** ^{NS}	
Taste	CSO	5.9±1.7	6.4±2.0	6.8±0.9	5.5±1.9	5.6±1.6	**2.17**^{NS}
	GNO	6.9±1.3	6.3±1.4	5.7±1.8	6.2±1.6	5.7±1.5	**2.05** ^{NS}
	't'	**2.17***	**0.18**^{NS}	**2.46***	**1.24**^{NS}	**0.29**^{NS}	
Odor	CSO	6.3±1.0^{a}	6.6±1.2^{ad}	6.6±1.0^{ad}	5.5±1.5^{bc}	5.1±1.3^{b}	**6.00****
	GNO	7.0±1.0^{a}	6.8±1.3^{a}	6.5±1.4^{ac}	5.9±1.1^{bc}	5.2±1.4^{b}	**6.59*****
	't'	**2.17***	**0.37**^{NS}	**0.25**^{NS}	**0.91**^{NS}	**0.23**^{NS}	
Overall acceptability	CSO	6.0±1.3^{a}	6.4±1.5^{a}	7±0.79^{b}	5.6±1.7^{a}	5.6±1.6^{a}	**3.12***
	GNO	6.8±1.0^{a}	6.6±1.3^{ab}	5.85±1.8^{b}	5.9±1.3^{b}	5.7±1.4^{b}	**2.47***
	't'	**2.06***	**0.44**^{NS}	**2.53***	**0.64**^{NS}	**0.20**^{NS}	

Note: 1. h-hours; 2. *- significant at p<0.05, ** - significant at p<0.01, *- significant at p<0.001, NS- not significant; 3. Indicators for sensory scores from 9-1 (9-like extremely, 8-like very much, 7-like moderately, 6-like slightly, 5-neither like nor dislike, 4- dislike slightly, 3-dislike moderately, 2-dislike very much, 1-dislike extremely) ; 4. Dissimilar superscripts in each row between the columns indicate significant differences amongst the values**

Flavor, taste and odor scores of french fries are shown in Figure 5.2.1.2, 5.2.1.3 and 5.2.1.4 respectively. Mean flavor scores (F-test) of french fries prepared in both the oils showed significant reduction ($p<0.05$) as the duration of frying increased. However, student 't' test showed significant higher ($p<0.05$) score of french fries fried in CSO as compared to GNO (Table 5.2.1.1).

With respect to taste, french fries fried in GNO were more preferred than CSO prepared fries up to 6 h of intermittent frying duration. However, at 11 h interval, taste scores for french fries fried in CSO were significantly higher ($p<0.05$) than GNO fried fries and thereafter the taste scores reduced in both the oils (Table 5.2.1.1).

A peculiar/different strong nutty odor of GNO was noticed during the initial hours of frying (up to 4 h of intermittent frying). However, as the duration of intermittent frying increased from 0 to 21 h the odor scores of both GNO and CSO fried french fries decreased significantly ($p<0.001$) shown in Table 5.2.1.1. Between the GNO and CSO fried french fries significant ($p<0.05$) difference were seen only at 0 h.

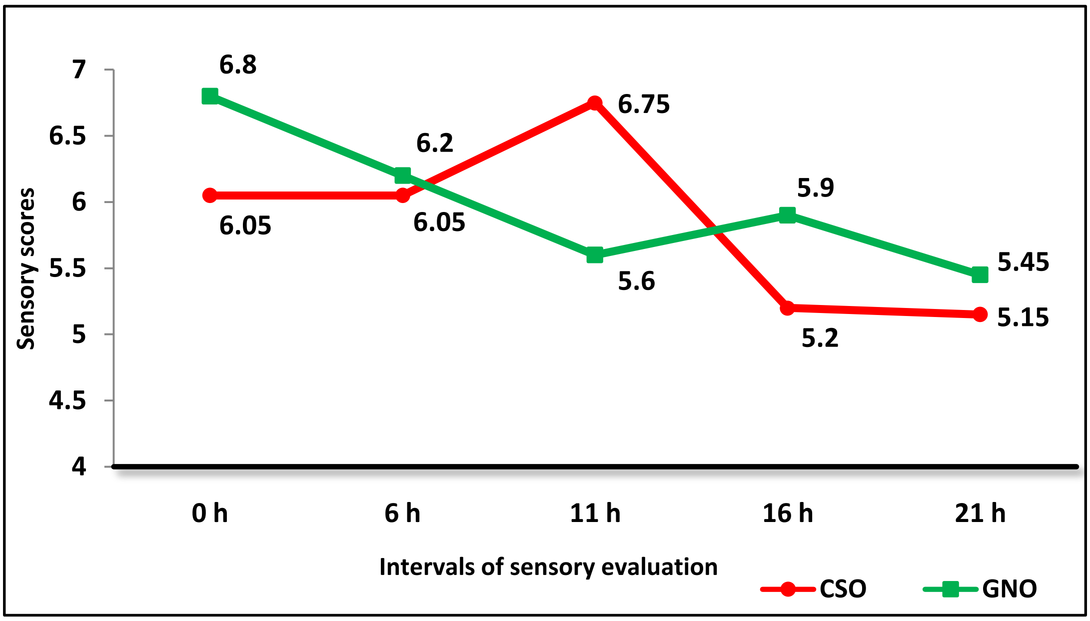


Figure 5.2.1.2: Mean sensory scores for flavor of french fries fried in CSO and GNO at intermittent intervals

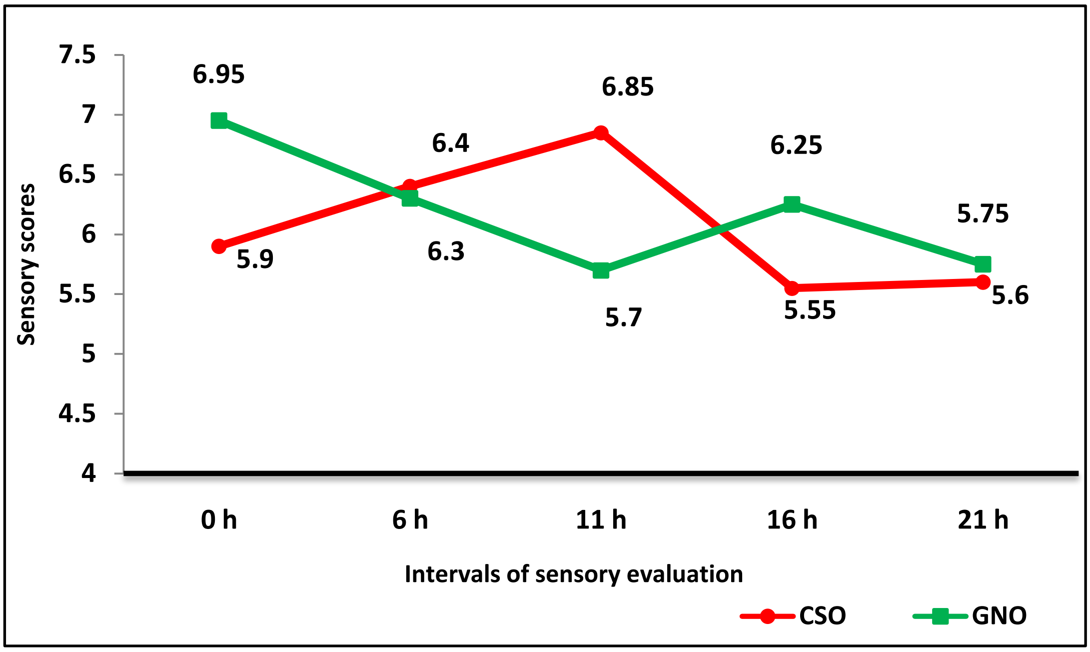


Figure 5.2.1.3: Mean sensory scores for taste of french fries fried in CSO and GNO at intermittent intervals

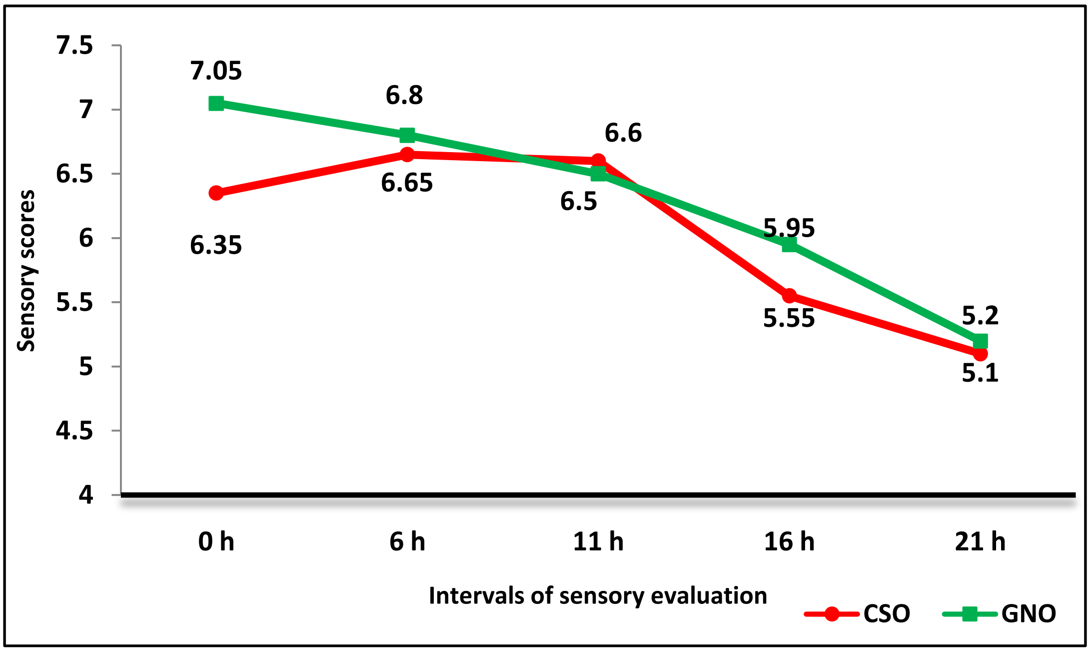


Figure 5.2.1.4: Mean sensory scores for odor of french fries fried in CSO and GNO at intermittent intervals

The overall acceptability mean scores of french fries fried in CSO and GNO is shown in Figure 5.2.1.5. At first hour of frying, the mean scores for overall acceptability of french fries prepared in GNO showed significantly higher ($p<0.05$) than those fried in CSO. However, at 11 h of frying overall acceptability of CSO fried french fries scores were significantly higher ($p<0.05$) than GNO fried fries as there score may have been influenced by the flavor scores.

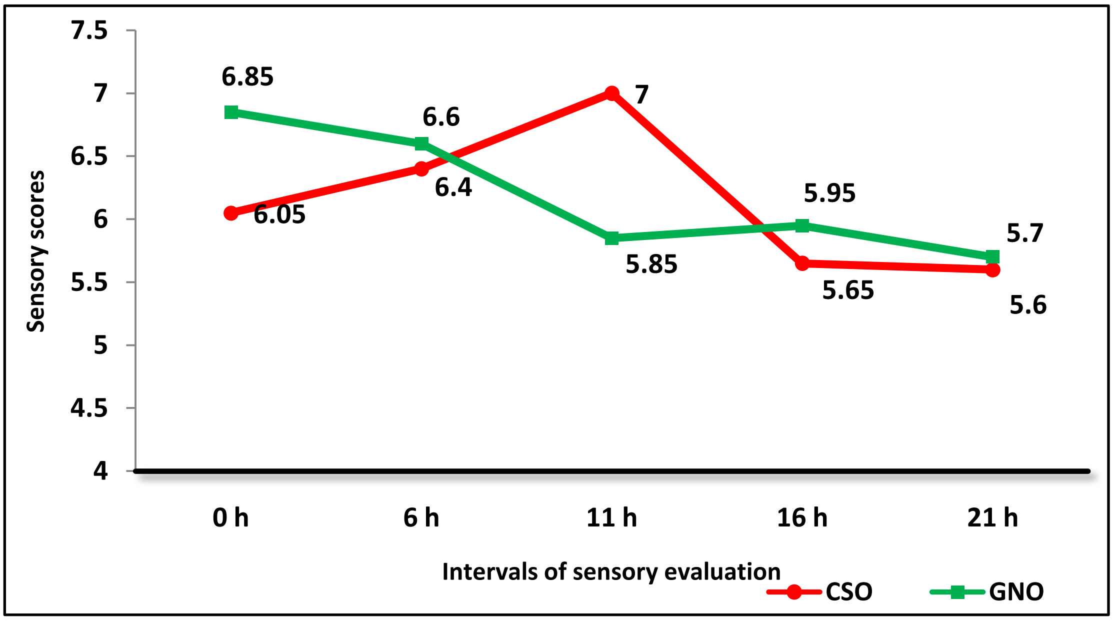


Figure 5.2.1.5: Mean sensory scores for overall acceptability of french fries fried in CSO and GNO at intermittent intervals

The flavor of food comprises three components- odor, taste and mouth feel. Therefore relation of flavor with these sensory attributes was investigated. Table 5.2.1.2 shows the strong relation of flavor with odor, taste and greasiness of french fries fried in CSO and GNO.

Pearson's correlation coefficient test reveal a strong relationship between the flavor scores and overall acceptability scores of french fries $r=0.96$ (CSO and GNO).

Table 5.2.1.2: Correlation coefficient of flavor with odor, greasiness, overall acceptability and taste scores of french fries fried in CSO and GNO oil at intermittent intervals

Attribute	Type of oil	
	CSO	GNO
	*Correlation coefficient (r)	
Flavor-odor	0.89	0.79
Flavor-greasiness	0.95	0.88
Flavor-overall acceptability	0.96	0.96
Flavor-taste	0.93	0.97

Note- *significant at p<0.05

5.2.2: Sensory quality of bhajias fried in CSO and GNO at intermittent durations

Bhajias fried in CSO and GNO at intermittent intervals were assessed for various sensory qualities like appearance, color, crispness, greasiness, flavor, taste, odor and overall acceptability.

Mean scores for appearance and color of bhajias are graphically shown in Figure 5.2.2.1 and 5.2.2.2 respectively. F-test revealed no significant difference in the mean scores for appearance and color of bhajias fried in both CSO and GNO as the period of intermittent frying increased from 0 h to 21 h. Also no significant difference was seen between CSO and GNO for appearance and color of bhajias (Table 5.2.2.1).

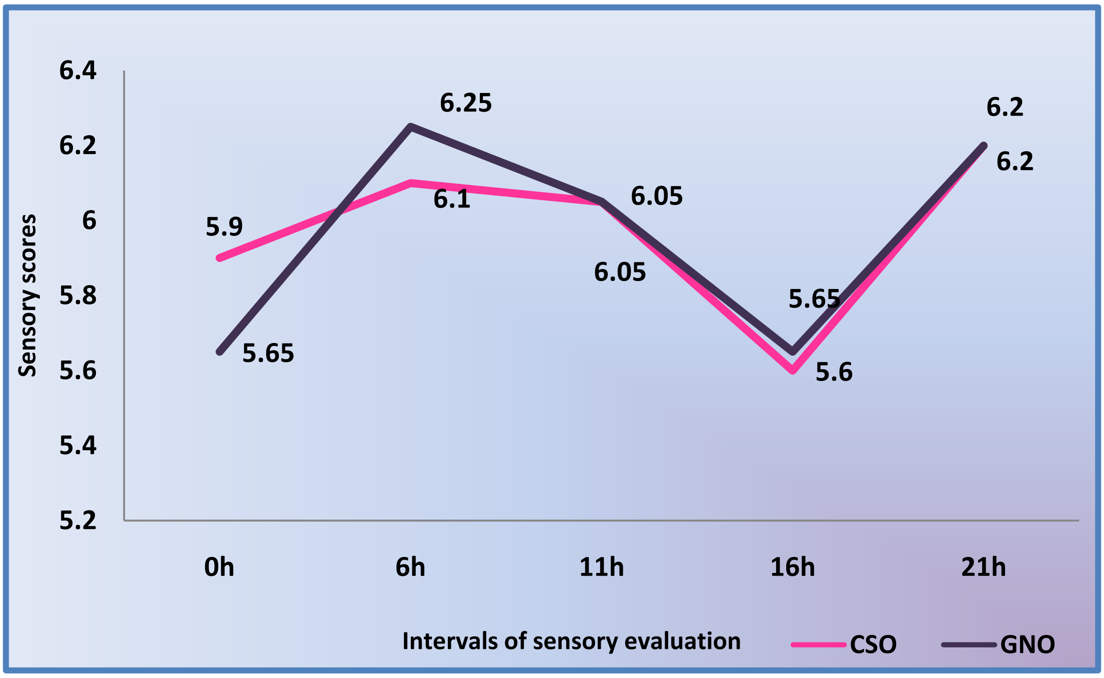


Figure 5.2.2.1: Mean sensory scores for appearance of bhajias fried in CSO and GNO at intermittent intervals

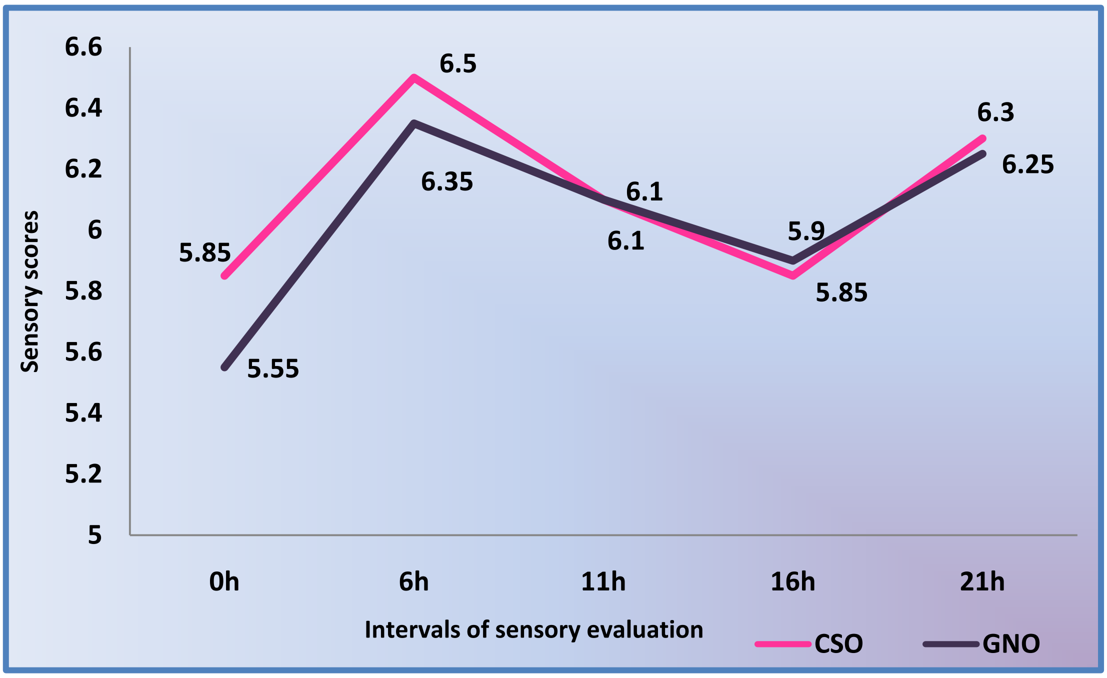


Figure 5.2.2.2: Mean sensory scores for color of bhajias fried in CSO and GNO at intermittent intervals

Table 5.2.2.1: Mean sensory scores of bhajias fried in CSO and GNO at intermittent duration of frying

Sensory Attributes	Oil	0 h	6 h	11 h	16 h	21 h	F-value
Appearance	CSO	5.9±1.71	6.1±1.21	6.05±1.28	5.6±1.14	6.2±1.54	**0.56** NS
	GNO	5.65±1.60	6.25±0.85	6.05±1.28	5.65±1.39	6.2±1.61	**0.91** NS
	't'	**0.47** NS	**0.45** NS	**0** NS	**0.12** NS	**0** NS	
Color	CSO	5.85±1.53	6.5±1.05	6.1±1.45	5.85±1.23	6.3±1.38	**0.90** NS
	GNO	5.55±1.54	6.35±1.39	6.1±1.37	5.9±1.37	6.25±1.37	**1.01** NS
	't'	**0.62** NS	**0.39** NS	**0** NS	**0.12** NS	**0.11** NS	
Crispness	CSO	5.45±1.67	5.55±1.73	5.55±1.39	5.25±1.55	6.05±1.43	**0.71** NS
	GNO	5.1±1.71	5.35±1.50	5.6±1.43	5.15±1.50	5.6±1.47	**0.49** NS
	't'	**0.65** NS	**0.39** NS	**0.11** NS	**0.21** NS	**0.98** NS	
Greasiness	CSO	5.1±1.33	5.3±1.38	4.6±1.35	4.0±1.56	4.7±1.95	**2.16** NS
	GNO	4.9±1.37	5.15±1.39	4.5±1.73	4.05±1.76	4.35±2.06	**1.36** NS
	't'	**0.47** NS	**0.34** NS	**0.20** NS	**0.09** NS	**0.55** NS	
Flavor	CSO	5.9±1.97	6.45±1.28	5.85±1.46	5.4±1.39	5.4±1.85	**1.45** NS
	GNO	5.0±1.65	5.5±1.70	5.1±1.33	4.9±1.29	5.35±1.42	**0.56** NS
	't'	**1.56** NS	**1.20** NS	**1.70** NS	**1.18** NS	**0.10** NS	
Taste	CSO	6.2±1.88	6.5±1.40	6.0±1.45	5.55±1.43	5.5±2.09	**1.30** NS
	GNO	5.15±1.57	5.6±1.54	5.05±1.23	4.75±1.12	5.65±1.04	**1.68** NS
	't'	**1.92** NS	**1.94** NS	**2.23***	**1.97** NS	**0.29** NS	
Odor	CSO	6.1±1.83	6.15±1.14	5.65±1.53	6.05±1.05	5.35±1.84	**1.05** NS
	GNO	4.95±1.90	5.7±0.86	5.1±0.91	4.9±1.45	5.55±1.36	**1.44** NS
	't'	**1.95** NS	**1.41** NS	**1.38** NS	**2.88****	**0.34** NS	
Overall acceptability	CSO	5.9±1.80	6.5±1.10	6.0±1.49	5.45±1.43	5.45±1.96	**1.53** NS
	GNO	5.2±1.36	5.5±1.36	5.25±1.37	5.15±1.35	5.6±1.54	**0.40** NS
	't'	**1.39** NS	**2.56***	**1.66** NS	**0.68** NS	**0.27** NS	

Note: 1. h-hours; 2. *- significant at p<0.05, ** - significant at p<0.01, *- significant at p<0.001, NS- not significant; 3. Indicators for sensory scores from 9-1 (9-like extremely, 8-like very much, 7-like moderately, 6-like slightly, 5-neither like nor dislike, 4- dislike slightly, 3-dislike moderately, 2-dislike very much, 1-dislike extremely)**

Plate 5.2.2.1 shows the appearance of bhajias fried in CSO at initial hour of intermittent frying and Plate 5.2.2.2 depict the change in appearance of bhajias at 25 h of intermittent frying in the same oil.

Plate 5.2.2.1: Appearance of bhajias fried in CSO at initial hours of frying

Plate 5.2.2.2: Change in appearance of bhajias fried in CSO at the end of frying hours

At the initial hours bhajias fried in CSO showed better scores for crispness as compared to bhajias fried in GNO (Figure 5.2.2.3). However, the crispness scores of bhajias fried in CSO increased at the end of intermittent frying as compared to bhajias fried in GNO but this increase was not statistical significant (Table 5.2.2.1).

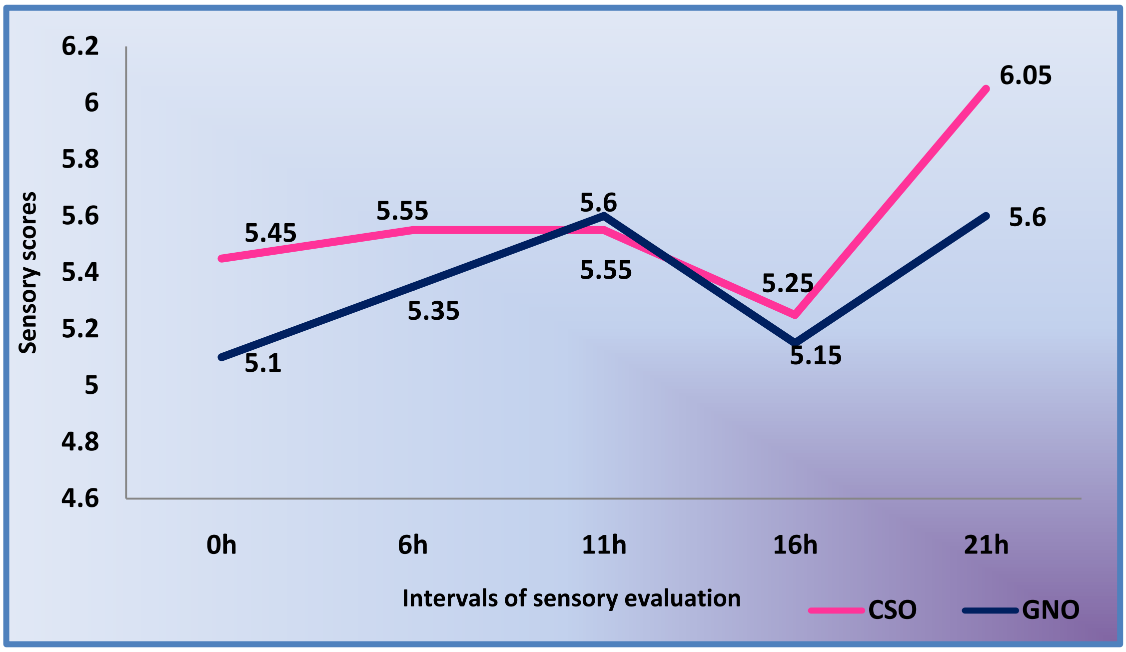


Figure 5.2.2.3: Mean sensory scores for crispness of bhajias fried in CSO and GNO at intermittent intervals

Greasiness scores (Figure 5.2.2.4) of bhajias fried in CSO and GNO slightly decreased up to 21 h of intermittent frying, representing more oil absorption as the duration of frying increased. Greasiness scores of bhajias fried in cottonseed oil were higher as compared to bhajias fried in groundnut oil. Table 5.2.2.1 showed no statistical difference in between the intermittent frying intervals of bhajias (ANOVA) and between the sensory scores of bhajias fried in two different oils (CSO and GNO) ('t').

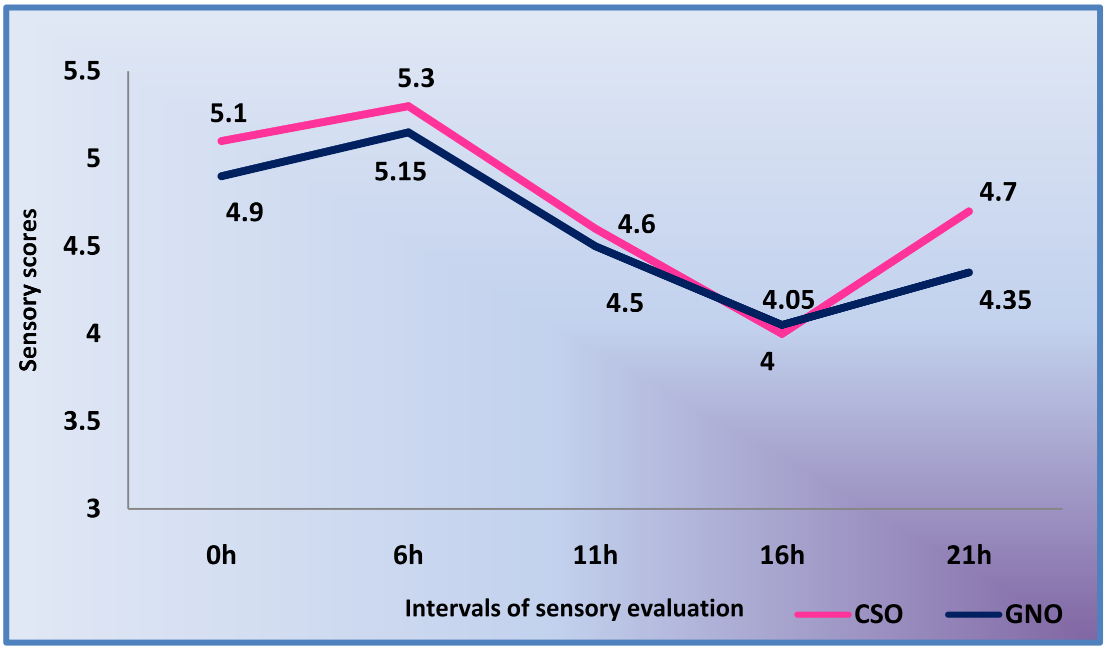


Figure 5.2.2.4: Mean sensory scores for greasiness of bhajias fried in CSO and GNO at intermittent intervals

Mean flavor scores of bhajias fried in CSO and GNO are shown in Figure 5.2.2.5. These scores increased up to 6 h of intermittent frying, thereafter, they decreased slightly. The reduction in flavor scores for both the oils was not statistically significant.

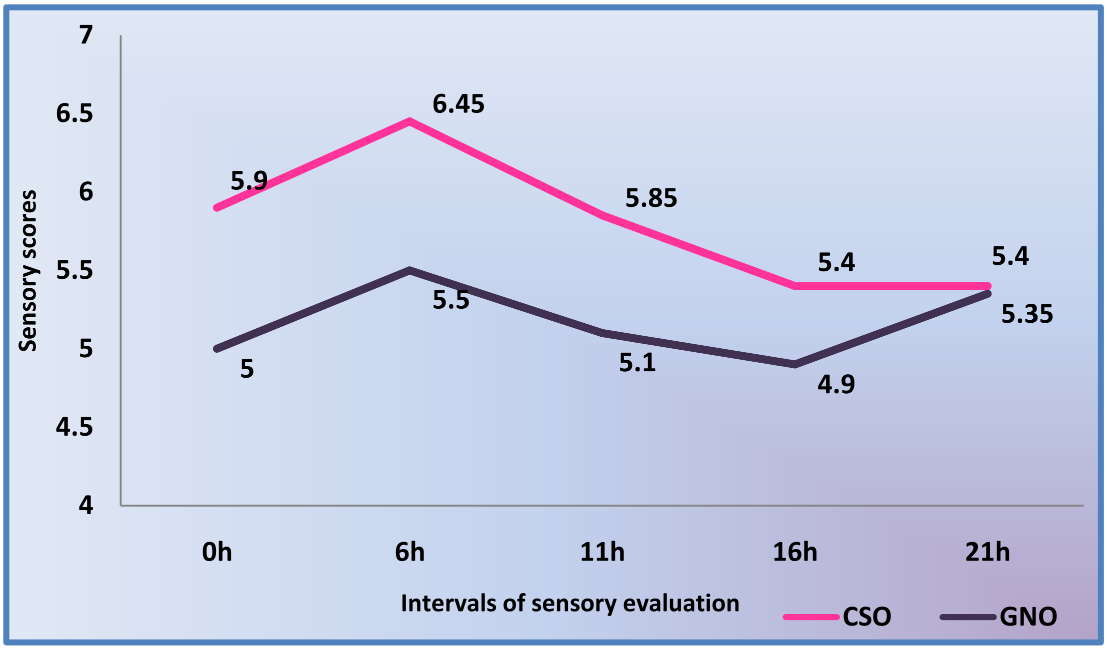


Figure 5.2.2.5: Mean sensory scores for flavor of bhajias fried in CSO and GNO at intermittent intervals

Mean scores for taste of bhajias can be seen in Figure 5.2.2.6. Mean taste scores of bhajias prepared in CSO and GNO; also showed similar pattern like overall acceptability of bhajias. Mean sensory scores for taste of bhajias fried in CSO were higher than those fried in GNO. ANOVA revealed no significant difference between sensory scores of bhajias fried in two oils (Table 5.2.2.1).

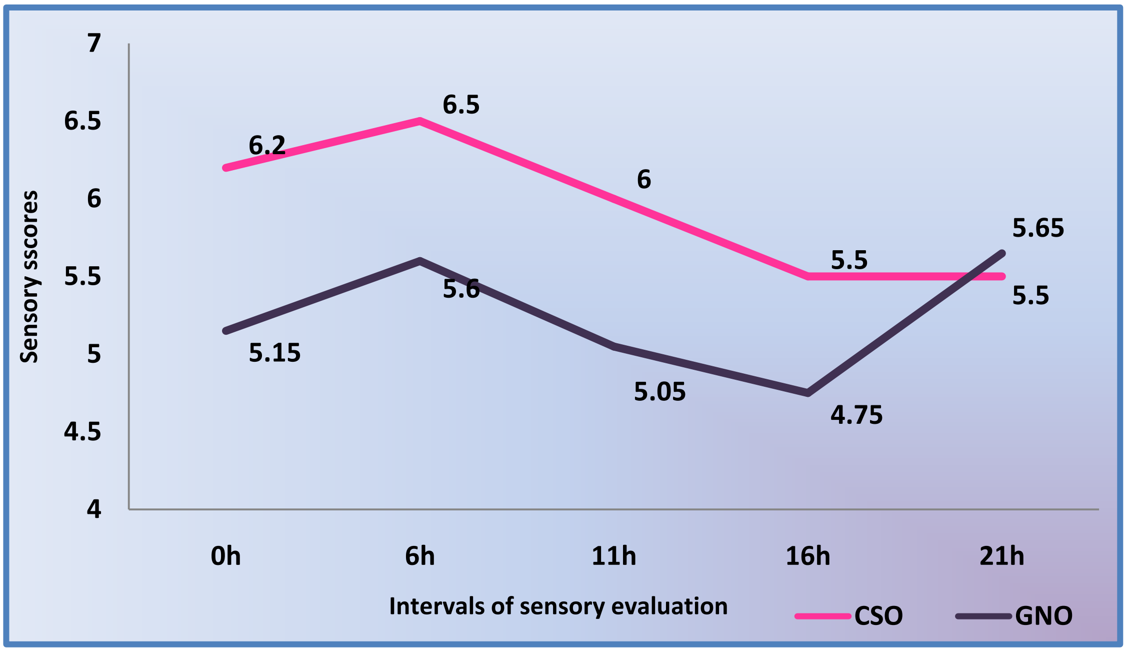


Figure 5.2.2.6: Mean sensory scores for taste of bhajias fried in CSO and GNO at intermittent intervals

Bhajias prepared in CSO scored higher odor scores at initial hours of frying as compared to bhajias fried in GNO shown in Figure 5.2.2.7. The odor scores of bhajias fried in GNO significantly remained low during intermittent frying up to 16 h when compared to bhajias fried in CSO. However, this difference was not statistically significant up to 11 h of intermittent frying. And at 16 h of intermittent frying the odor scores of GNO fried bhajias reduced significantly (Table 5.2.2.1).

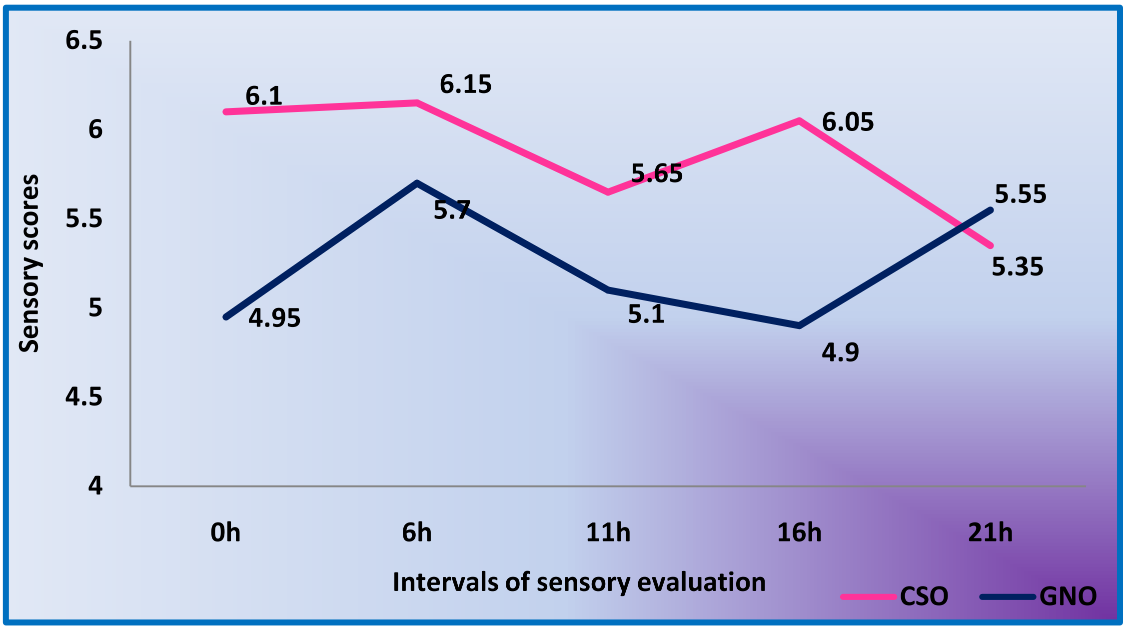


Figure 5.2.2.7: Mean sensory scores for odor of bhajias fried in CSO and GNO at intermittent intervals

Overall acceptability of bhajias fried in both the oils showed decrease in sensory mean scores during the 21 h of intermittent frying (Figure 5.2.2.8). ANOVA (F-test) showed non-significant difference in the overall acceptability scores of bhajias as the duration of intermittent frying increased from 0 to 21 h. However, at 6 h CSO fried bhajias showed significantly ($p<0.05$) higher overall acceptability scores than those fried in GNO (Table 5.2.2.1).

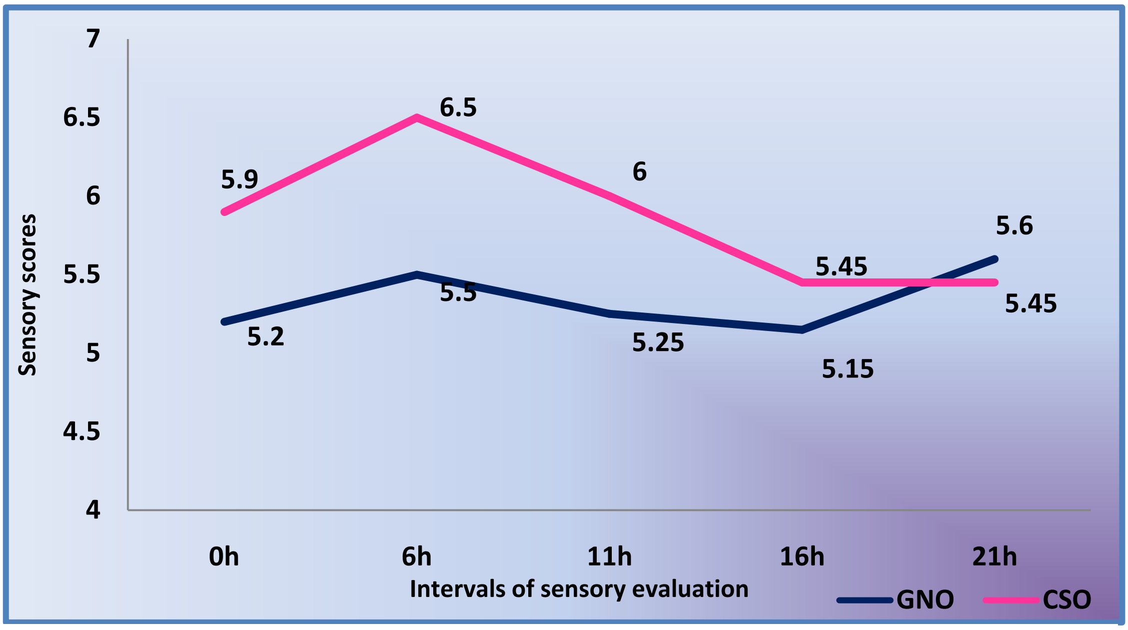


Figure 5.2.2.8: Mean sensory scores for overall acceptability of bhajias fried in CSO and GNO at intermittent intervals

Table 5.2.2.2 shows strong relation of flavor with odor, taste and greasiness of bhajias fried in CSO and GNO. Pearson's correlation coefficient test revealed a strong relationship between the flavor scores and overall acceptability scores of bhajias r=0.99 and 0.91 in CSO and GNO respectively.

Table 5.2.2.2: Correlation coefficient of flavor with odor, greasiness scores and overall acceptability of bhajias fried in CSO and GNO at intermittent intervals

Attribute	Type of oil	
	CSO	GNO
	*Correlation coefficient (r)	
Flavor-odor	0.55	0.99
Flavor-greasiness	0.80	0.55
Flavor-overall acceptability	0.99	0.91
Flavor-taste	0.97	0.93

Note- *significant at $p<0.05$

5.2.3: Comparison of sensory mean scores of non-coated (french fries) and batter coated (bhajias) potatoes fried in CSO and GNO

Figure 5.2.3.1 and 5.2.3.2 show the difference in sensory scores of non-coated and coated potatoes fried in CSO at intermittent intervals. Appearance, flavor, taste, odor and overall acceptability of non-coated potatoes were significantly higher ($p<0.05$) at 11 h interval than batter coated potatoes fried in CSO. Crispness of batter coated potatoes was significantly higher ($p<0.05$) than non-coated potatoes at the end (21 h) of intermittent frying hours.

Sensory scores of GNO fried non-coated and coated potatoes are shown in Figure 5.2.3.3 and 5.2.3.4. At different intervals of frying non-coated potatoes fried in GNO showed significant higher ($p<0.001$) scores for appearance, flavor, taste, odor and overall acceptability than batter coated potatoes. However, crispness and greasiness scores of both coated and non-coated potatoes did not show any significant difference at any hour of intermittent frying.

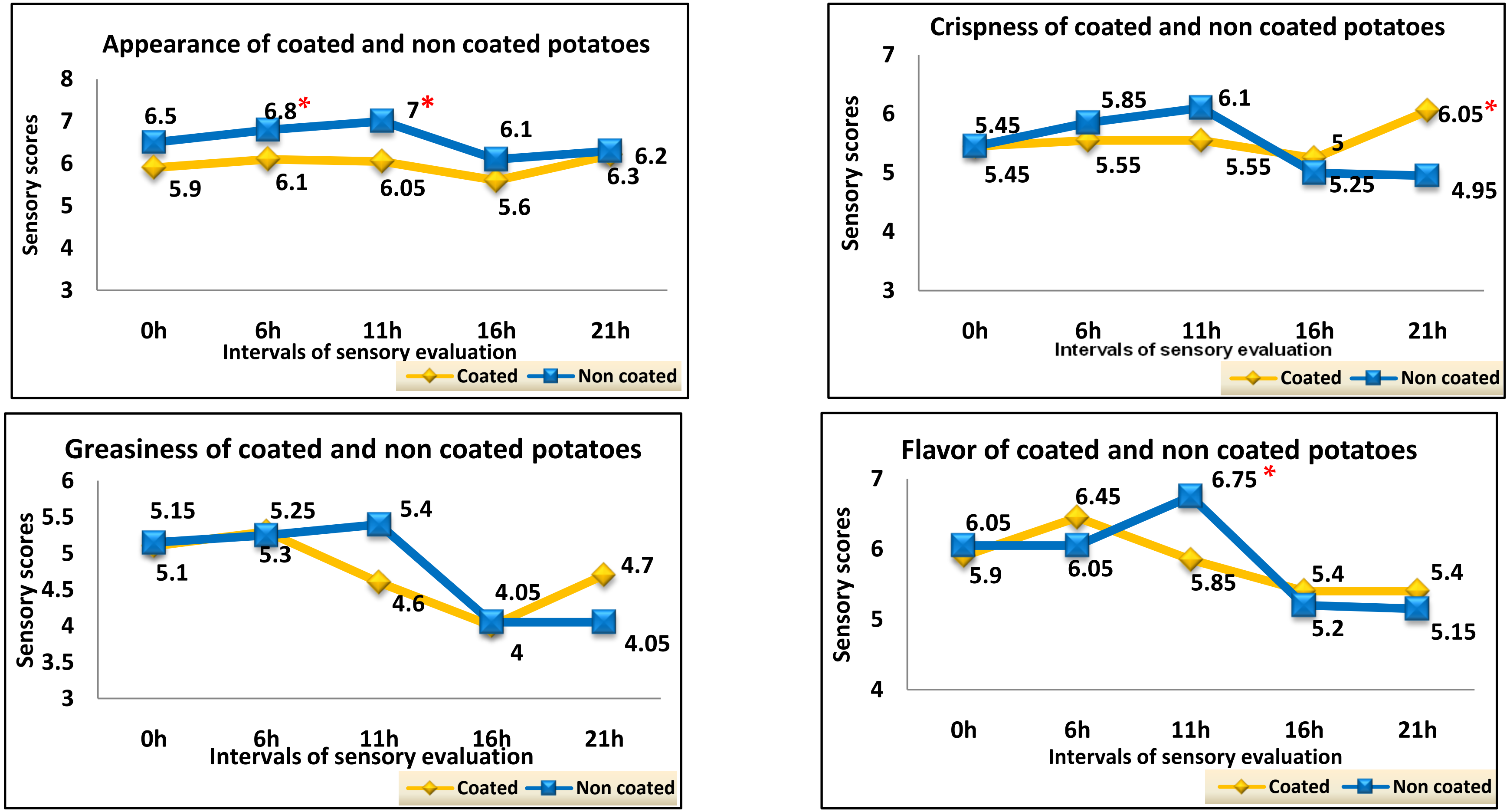


Figure 5.2.3.1: Comparison of sensory mean scores of coated and non coated potatoes fried in CSO at intermittent intervals

Note- *-significant at $p<0.05$

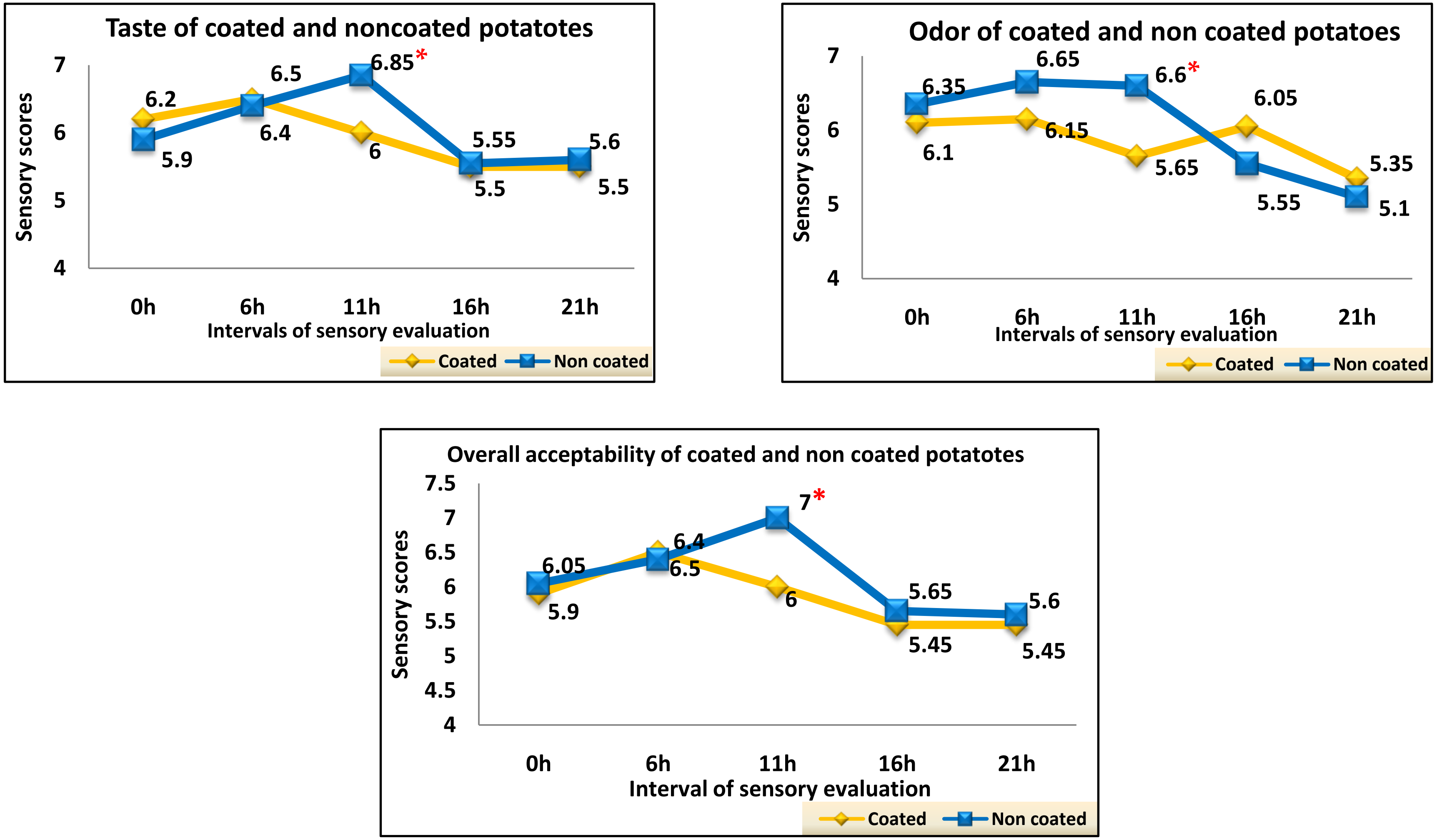


Figure 5.2.3.2: Comparison of sensory mean scores of coated and non coated potatoes fried in CSO at intermittent intervals

Note- *-significant at $p<0.05$

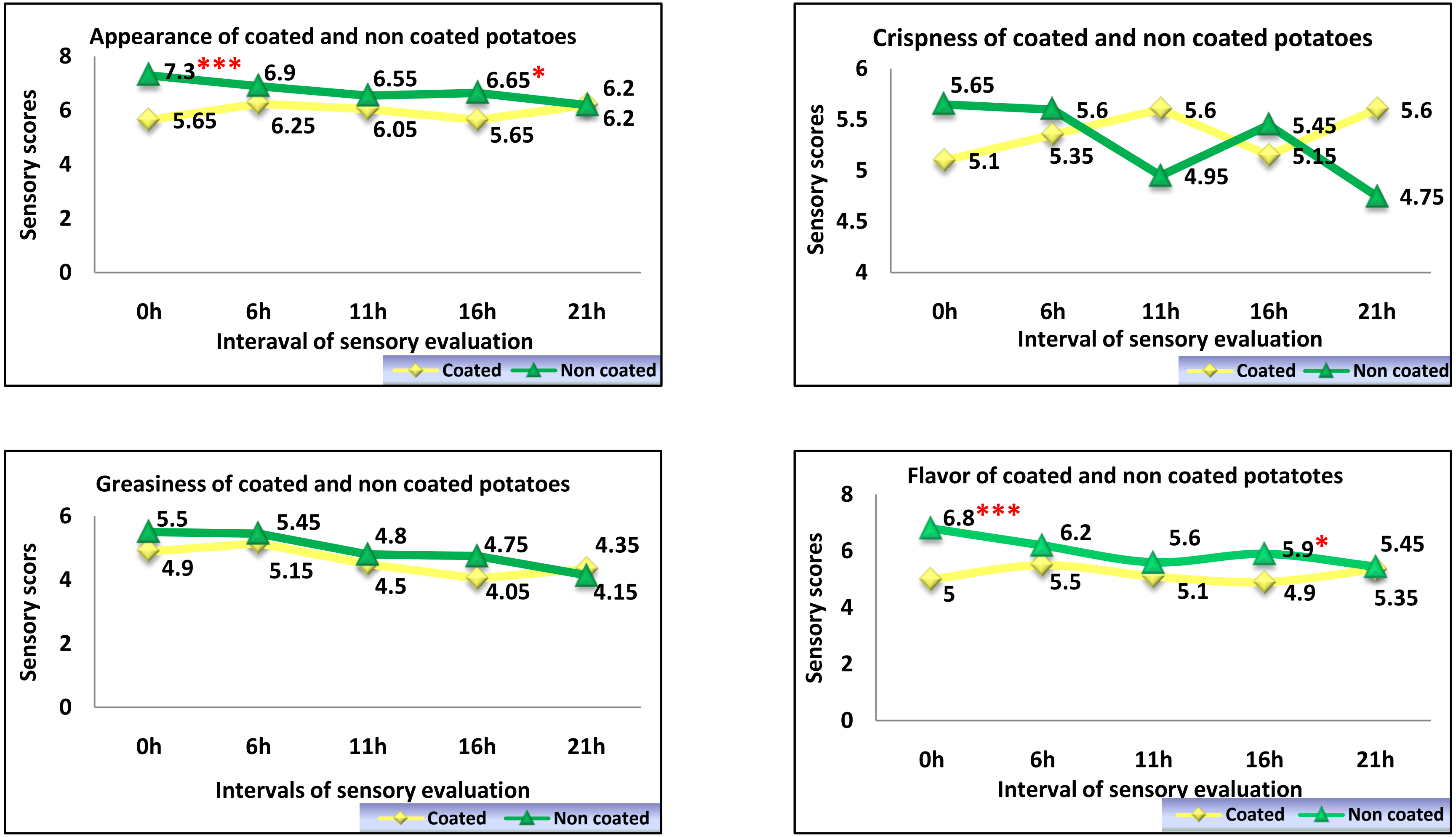


Figure 5.2.3.3: Comparison of sensory mean scores of coated and non coated potatoes fried in GNO at intermittent intervals

Note- *-significant at $p<0.05$; ***-significant at $p<0.001$

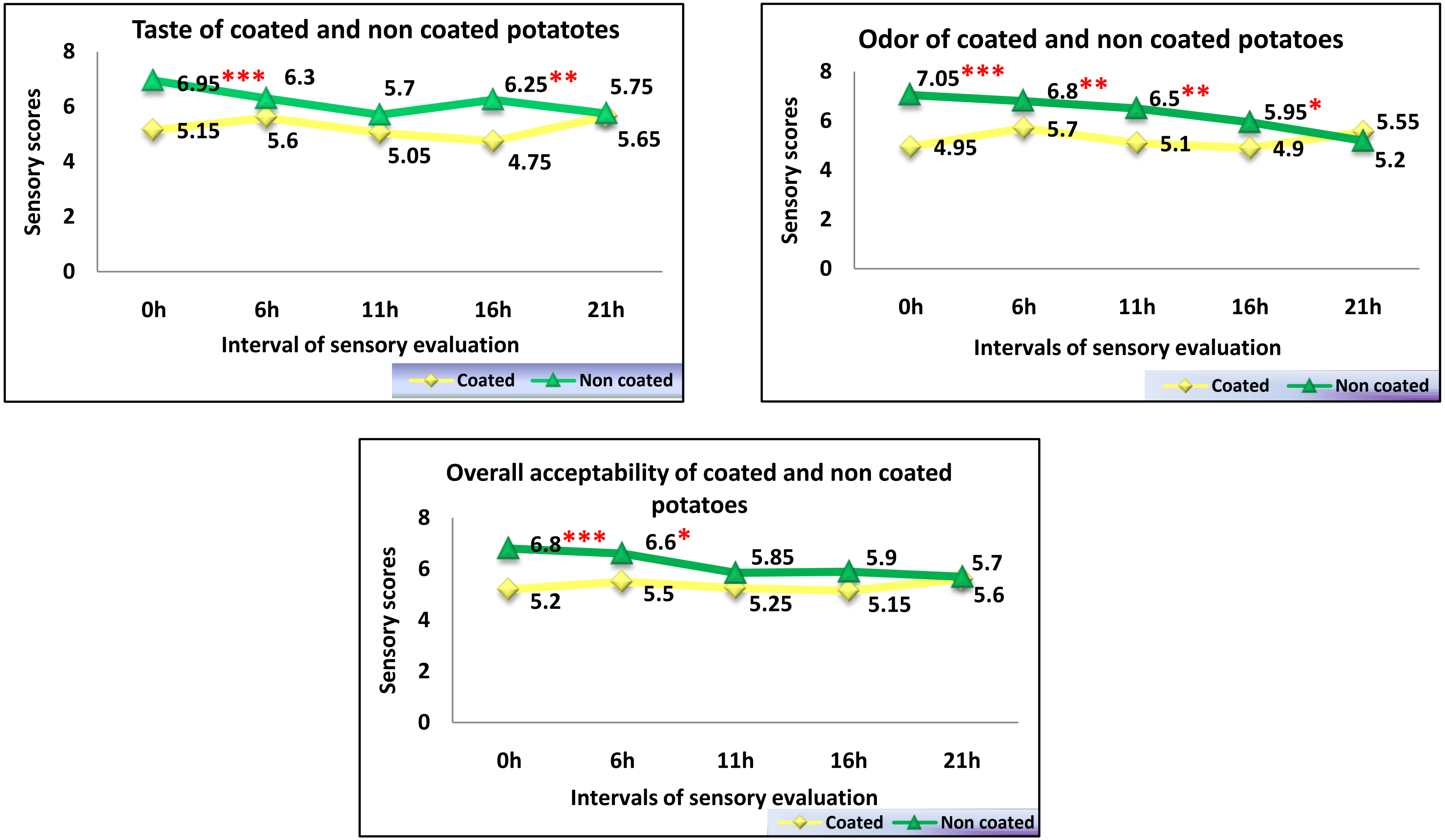


Figure 5.2.3.4: Comparison of sensory mean scores of coated and non coated potatoes fried in GNO at intermittent intervals

Note- *-significant at p<0.05; **-significant at p<0.01; *-significant at p<0.001**

5.2.4: Oil uptake by french fries and bhajias fried in CSO and GNO up to 25 h of intermittent frying.

Frying of food product results in evaporation of water present in raw material and this place is partially replaced by oil consequently influencing the properties of final product. Oil uptake by french fries and bhajias fried in CSO and GNO up to 25 h of intermittent frying is shown in Table 5.2.4.1 and 5.2.4.2.

Between the fried products, intermittent frying of bhajias showed higher oil uptake as compared to french fries. Under the similar frying conditions, oil uptake of GNO used for bhajias and french fries was 19.5% and 12% respectively. Whereas CSO oil uptake was 15.6% and 11.5% for bhajias and french fries respectively.

Table 5.2.4.1: Total oil used after 25 h of intermittent french fries frying

Oil	Initial level of oil used for frying	Total oil removed for chemical analysis	Actual amount of oil used for frying	Amount of oil left after 25 h of intermittent frying	Amount of oil absorbed (mean) for 25 batches of frying	Amount of oil used /batch for 90g french fries	% Oil uptake
CSO	1500	300	1200	940	260	10.4	11.5%
GNO	1500	300	1200	930	270	10.8	12%

Table 5.2.4.2: Total oil used up to 25 h of intermittent bhajias frying

Oil	Initial level of oil used for frying	Total oil removed for chemical analysis	Actual amount of oil used for frying	Amount of oil left after 25 h of intermittent frying	Amount of oil absorbed (mean) for 25 batches of frying	Amount of oil used /batch for 200g bhajias	% Oil uptake
CSO	1354	280	1074	293.8	780.2	31.2	15.6%
GNO	1348	280	1068	84.6	983.4	39.3	19.5%

PHASE II- RESULT HIGHLIGHTS

French fries

- *Intermittent frying of french fries in CSO and GNO showed a non significant change for appearance, color, crispness, greasiness and taste scores.*
- *Flavor, odor and overall acceptability scores showed a significant reduction ($p<0.05$) with the increase in frying hours up to 21 h of intermittent frying.*
- *Taste, odor and overall acceptability of GNO fried french fries had significantly higher ($p<0.05$) scores than french fries fried in CSO at initial hour (0 h) of frying.*
- *At 11 h of intermittent frying french fries fried in CSO showed significantly higher ($p<0.05$) sensory scores for crispness, taste, flavor and overall acceptability than those fried in GNO.*
- *After 11 h of intermittent frying, the flavor, odor and overall acceptability of both CSO and GNO fried fries deteriorated with no significant difference between scores of french fries fried in both the studied oils.*

Bhajias

- *Bhajias fried in both CSO and GNO showed non significant change in sensory attributes during the intermittent frying up to 21 h.*
- *The crispness scores of bhajias improved in both the oils during the 21 h of intermittent frying.*
- *CSO fried bhajias scored higher up to 11 h of frying than GNO fried bhajias; afterward no changes in sensory attributes were observed in the oils.*

Comparison between sensory scores of french fries and bhajias (non-coated vs. batter coated) fried in CSO and GNO at intermittent intervals

- *At 0 h frying, french fries fried in GNO showed significantly higher ($p<0.05$) scores for appearance, flavor, taste, odor and overall acceptability than bhajias.*
- *At 11 h of intermittent frying significantly higher ($p<0.05$) scores for appearance, flavor, taste, odor and overall acceptability of CSO fried french fries were observed than those fried in GNO.*
- *Bhajias fried in CSO showed significantly higher ($p<0.05$) scores for crispness than GNO fried bhajias at the end (21 h) of intermittent frying.*
- *Odor of GNO fried french fries were more acceptable up to 16 h of intermittent frying than bhajias fried in CSO.*

DISCUSSION

Deep-fat fried products, prepared from raw vegetables, cereals, legumes and their blends, are universally popular due to their desirable organoleptic profile (Annapure US, Singhal RS and Kulkarni PR, 1998). Frying oil acts as a heat transfer medium and contributes to the texture and flavor of fried food. Foods fried at the optimum temperature and time have golden brown color, are properly cooked, and crispy, and have optimal oil absorption (Blumenthal MM, 1991; Dobarganes C, Márquez-Ruiz G, and Velasco J, 2000).

Present phase of the study was undertaken to evaluate french fries and bhajias at intermittent intervals of frying.

The sensory qualities of french fries revealed no significant difference in the mean scores for appearance, color, crispness and taste of french fries fried in CSO (cottonseed oil) and GNO (groundnut oil) at the end of 21 h of intermittent frying. A study by Nor FM et al (2009) also reported non significant change in color, oiliness and crispness between samples when french fries were intermittently fried for 5 days at 180^0 C temperature in oil containing BHT (Butylated Hydroxy Toluene) and *Curcuma longa* (turmeric) extract.

The crispness of fried foods is greatly influenced by several factors like temperature, oil uptake and number of frying. Reduction in crispness scores of french fries fried in both the oils was observed as the duration of frying increased. However, at 11 h of intermittent frying, crispness of french fries prepared in CSO had significantly higher scores than those prepared in GNO. Another study showed significant decrease in crispness of potato chips during frying in low linolenic canola oil than sunflower and palm olein oil (Xu XQ et al, 1999). In the present study, higher crispness of french fries fried in CSO possibly be due to its high linolenic acid (0.34g/100g) than GNO containing only 0.21g/100g linolenic acid.

Taste of fried foods is influenced by several factors such as product fried, temperature including type of oil used and its fatty acid profile. Present study showed that at initial hours french fries fried in GNO were more acceptable due to its peculiar/different taste. Use of groundnut oil is high in Gujarat region could be the reason for more acceptability of french fries fried in GNO. When french fries were intermittently fried in GNO initially acceptable taste subsided and french fries prepared in CSO were more liked by the panelist. These results could be influenced by the alteration in fatty acid profile i.e. increase in oleic acid and decrease in linoleic acid of fried oil. Similar results were observed when potato chips fried in medium-high-oleic sunflower oil as compared to potato chips fried in high-linolenic canola oil (Xu XQ et al, 1999).

Present study, showed a significant ($p<0.05$) reduction in flavor intensity of french fries fried in CSO and GNO as the period of frying increased. Fried food flavor is partly derived from the formation of 2, 4-decadienal during the thermal oxidation of linoleic acid (Choe E and Min DB, 2007). Results of the present study are in accordance with the studies stating that fried food flavor of fries generally decreases as the percentage of oleic acid increases and percent linoleic acid decreases in the frying oil (Narasimhamurthy K, and Raina PL, 1998). This result probably justifies that in CSO fried french fries, at 11 h of frying desirable fatty acid profile must be at its optimum level required for good taste of fried product. In a study by Warner K, Orr P and Glynn M (1997) showed when potato chips fried in CSO having the rate of 16% oleic/55% linoleic acid had significantly higher intensity of fried food flavor than potato chips fried in the oil with either 63% oleic/23% linoleic acid or 78% oleic/12% linoleic acid.

Studies described that typical desirable fried flavor is produced at the optimal concentration of oxygen. Low amounts of oxygen produce poor and weak flavor, and high levels of oxygen produce off-flavor. Fried flavor compounds in fried foods are mainly volatile compounds formed from linoleic acid and are dienal, alkenals, lactones, hydrocarbons, and various cyclic compounds (Pokorny J, 1989; Choe M and Min DB, 2007). In the present study off flavor developed in the french fries at the end of 20 and 21 h of frying; as reported by sensory panelists could be due to development of other aldehydes such as nonanal, heptanal etc. as result of repeated frying (Tompkins C and Perkins EG, 1999; Warner K and Moser J, 2009).

Regards to odor it has been found that high oleic oils are more stable and produce less hexanal compounds (odor giving volatile compounds) than linoleic and linolenic rich oils (Warner K and Gupta M, 2005). Apparently, similar results were found in the present study which shows odor of groundnut oil fried french fries was notably higher than french fries fried in cottonseed oil. In another study, *pooris* fried in groundnut and coconut oil blend were more acceptable than those fried in palmolien and rice bran oil blend. This may be due to familiarity of the target groups with groundnut oil and absence of any dominant odor note of coconut oil (Raj PN, Prakash M and Bhat KK, 2006). As stated above in the present study also, because of continued culinary use of groundnut oil, sensory panelists may perhaps have developed a liking the products fried in GNO for its odor and flavor.

With respect to overall acceptability of french fries, high acceptability of CSO fried fries especially peaking at 11 h could possibly be due formation of 2, 4-decadienal which is considered as desired compound during frying of oil rich in linoleic acid (Warner K, Orr P and Glynn M, 1997). Study conducted by Xin XQ et al (1999) on six different oils showed, when potato chips were fried at 190^{0}C for 80 h intermittently in partially hydrogenated canola oil (low in linoleic acid) had significantly lower acceptability than its other frying counterparts (high linolenic acid<mid linolenic acid<palm olein<low linolenic acid<sunflower oil) having linoleic acid in the range of 13.8%-32.4%.

The popularity of foodstuffs covered with tempura-type frying battered products has increased worldwide (Patton D, 2005). In this type of food, a chemically leavened batter serves as the outer coating of the food piece; giving good visual and structural characteristics to the product (Loewe R, 1993). Popularity and simultaneous increase in demand of these products amongst the consumers ensure good sensory acceptability of battered foods. Many existing studies on frying batters mainly analyze the characteristic of the basic ingredient, wheat flour for their sensory qualities (Cunningham FE and Tiede LM, 1981; Hsia HY, Smith DM and Steffe JF, 1992).

Another popular deep fried product consumed in all sections across the ethnic groups of India was also studied for their sensory qualities at intermittent intervals of frying using CSO and GNO. Potatoes coated with bengal gram flour (Bhajias) are popular snack food, were assessed for their sensory qualities at intermittent intervals. A non significant increase in appearance and color scores noticed in bhajias fried in CSO and GNO as the duration of frying increased from 0 h to 21 h. Study by Shih FF et al (2005) revealed, when okras were coated with varying levels of rice flour for deep frying, all the 3 studied formulations did not differ significantly for appearance attribute while the color scores improved significantly giving a desirable golden brown intensity. Baixauli R et al (2002) showed color of the fried battered squid rings was affected by both frying temperature and frying time. Change in color of fried products to golden brown color as the result of maillard reaction that depends on the content of reducing sugars and amino acids or proteins at the surface and temperature and time of frying (Nawar WW, 2000; Warner K, 2004).

Crispness is a highly valued and universally liked textural characteristic that indicates freshness and high quality. Probing into consumer attitudes to texture and its specific attributes, Szczesniak AS and Kahn EE (1971) concluded that crispness appears to be the most versatile single texture parameter. In the present study crispness scores of bhajias fried in polyunsaturated rich CSO had higher values as compared to monounsaturated rich GNO. However, F-test showed no significant change in crispness scores of bhajias. When different levels of additives used in *diamond cuts*- wheat flour based snack, deep fried in sunflower oil non significant change were observed in textural quality of the final product (Gowri BS et al, 2008). In an another study, where batter coated (wheat flour, baking powder, and three different gums; guar, xanthan and locust bean) frozen fish fillets were fried in hydrogenated palmolein margarine, no significant difference in appearance and texture was seen; indicating little contribution of the additives in the batter to textural qualities of the end product (Kilincceker O, Dogan IS and Kucukoner E, 2009).

In one study when breaded chicken nuggets were deep fried, cooked in convention oven or in microwave oven it was found that crispness in breaded chicken nuggets cooked in a deep-fat fryer was significantly crispier ($p<0.05$) than chicken nuggets cooked in either a convection oven or a microwave oven (Antonova I and Mallikarjunan P, 2004). Although in our study only one system of frying was used-open pan frying, studies have indicated varying effects on the textural quality of end product when different frying systems were used. This study indicates that crispier bhajias (the most desirable quality of the product) can be tried out by frying them using a deep fat fryer.

Various studies have shown that greasiness of fried foods is dependent on time and temperature of frying (Farkas BE et al, 1992; Gamble MH and Rice P, 1988; Pinthus EJ, Weinberg P and Saguy IS, 1993). Present work showed that greasiness of bhajias prepared in cottonseed oil was more than groundnut oil. However, there was no significant change observed in the greasiness scores up to 21 h of intermittent frying for both the oils. A study by Du-Ling et al (1998) observed that as the frying process progressed, an outer crust is formed on the product that made it more difficult for fat to penetrate into the product. Pokorny J and Reblova Z (1999) studied the transfer of oil to fried product and they concluded that pre-frying, battering and pre-heating of products may probably be good methods to inhibit absorption of oil during frying. No change in greasiness of the fried product was seen when coating of wheat flour and corn flour on chicken patties and resistant starch on frozen squid rings was done (Mah E and Brannan RG, 2009; Sanz T, Salvador A and Fiszman SM, 2008).

Extent of duration of frying did not alter the flavor, taste and odor of bhajias in both the oils. However, bhajias prepared in CSO showed better flavor, taste and odor scores as compared to GNO fried bhajias. Better scores of bhajias fried in CSO could be due to linoleic acid, as earlier reported studies said, linoleic acid is responsible for desirable deep-fat fried flavor (Warner K, Orr P and Glynn M, 1997). In addition, flavor of fried foods also depends on the type of oil and number of fryings (Prevot A et al, 1988).

In the present study, although the bhajias were fried 25 times in the same oil no significant changes were observed in the flavor of bhajias. The flavor of bhajias are depend on the taste, present taste results are comparable with the flavor scores where cottonseed oil fried bhajias had better scores than those fried in groundnut oil. Taste is the sum of the sensations perceived which is attributed to the inherent chemical compounds of food and to a greater extent by flavor and off-flavor imparted by the oil types used (Ikpeme CAE, Eneji CA and Essiet U, 2007). Like rest of the sensory parameters overall acceptability of cottonseed oil prepared bhajias was higher than those of bhajias fried in groundnut oil. Better overall acceptability scores of cottonseed oil fried bhajias may perhaps be the influence of other sensory attributes i.e. flavor, taste and odor.

In the present study, bhajias and french fries fried in GNO showed higher oil uptake than CSO. Similar results were obtained in a study conducted on legumes and cereal based deep-fried snacks fried in different vegetable oils. Highest oil uptake was observed by peanut oil (35.9%) and lowest by cottonseed oil (30.6%) (Annapure US, Sinhal RS and Kulkarni PR, 1998). Kita A, Lisinska G and Golubowska G (2007) revealed that fat absorption is greatly influenced by frying temperature. Frying at higher temperature (190^{0}C) in peanut oil decreased the oil uptake in potato crisps.

To conclude, frying of french fries alters the sensory qualities when fried intermittently up to 21 h whereas bhajias showed no significant change in sensory qualities when fried up to 21 h of intermittent frying. In view of overall acceptability, french fries fried in GNO were more acceptable than CSO prepared fries (up to 6 h of intermittent frying).

CHAPTER 5

RESULTS AND DISCUSSION

The broad objective of the present study was to assess the frequency of fried food intake by Gujarati housewives and its association with their morbidity profile, assess the sensory qualities of french fries and bhajias fried in cottonseed and groundnut oil at intermittent intervals, determine the intermittent frying stability of cottonseed and groundnut oil, and also to assess the food safety and frying practices prevailing at the Government run food outlet at Vadodara railway station.

This chapter presents the results of the respective phases of the study followed by discussion of respective phase under the following heads:

5.1 Phase I - Fried food intake, knowledge on fats and oils and frying practices of the Gujarati housewives of urban Vadodara and its association with the prevalence of non-communicable diseases (NCDs).

5.2 Phase II - Sensory qualities of french fries and bhajias fried in cottonseed oil (CSO) and groundnut oil (GNO) during intermittent frying.

5.3 Phase III - Chemical changes due to thermal degradation of intermittently deep fried cottonseed oil (CSO) and groundnut oil (GNO) as a result of french fries and bhajias frying.

5.4 Phase IV - Case study on prevailing food safety and frying practices in Jan aahar- a Government run food outlet at Vadodara railway station.

5.5 Phase V - Development of Nutrition Health Education (NHE) material in two languages on intake of edible oil, types, and on choices of oils for healthy living and problems during frying of edible oil and its storage.

PHASE I

5.1: FRIED FOOD INTAKE, KNOWLEDGE ON FATS AND OILS AND FRYING PRACTICES OF THE GUJARATI HOUSEWIVES OF URBAN VADODARA AND ITS ASSOCIATION WITH THE PREVALENCE OF NON-COMMUNICABLE DISEASES (NCDs)

Oil consumption is recognized as one of the major factors playing a significant adverse role in health hazard in terms of heart disease, diabetes, hypertension and cancers. In light of the multifaceted views and complex relationship between oil, fried food consumption and heath, the objective of this phase was to assess the fried food intake, knowledge on oils and fats and frying practices of Gujarati housewives of urban Vadodara and its association with the prevalence of NCDs.

In this phase of the study, 120 Gujarati housewives were surveyed for their practices on type of oil used for cooking; the survey was specifically aimed at collecting information on the consumption pattern of popularly consumed deep fried, shallow fried and sweets prepared at home and purchased from market of Vadodara and its association with prevalence of NCDs. The association between the knowledge level on *trans* fats and the education level of the subjects was also determined.

The results of this phase are presented under the following heads:

5.1.1: General information of Gujarati house wives

5.1.2: Anthropometric measurements, prevalence of non-communicable diseases (NCDs) and gastrointestinal (GI) problems

5.1.3: Food habits; preferred cooking method for a meal and its frequency

5.1.4: Consumption pattern of fried foods prepared at home and its association with prevalence of NCDs and GI problems

5.1.5: Consumption pattern of fried foods purchased from market and its association with prevalence of NCDs and GI problems

5.1.6: Eating out frequency; preferred cooking methods and foods preferred during long distance travelling

5.1.7: Oil consumption pattern, its use and association with prevalence of NCDs and GI problems

5.1.8: Use of leftover fried oil, containers used for oil storage and practices of storing fried oil

5.1.9: Knowledge on refrying and filtration of fried oil before storage

5.1.10: Changes observed in fresh oil upon frying and storage of fresh oil

5.1.11: Knowledge on oil blends and trans fats

5.1.1: General information of Gujarati housewives

As seen in Table 5.1.1 the education level of the subjects revealed that most women (57.5%) were graduate. Under activity pattern, exercise pattern of subjects revealed that almost 50% housewives exercised regularly in the form of brisk walking, yoga and jogging. Further, maximum number (62.5%) of subjects share household work with maid. According to Kuppuswamy (2007) classification family monthly income of 71.6% subjects was up to ₹10,000 and 28.3% families had more than ₹30,000 as their monthly income.

Table 5.1.1: General information of Gujarati housewives

General information	No (%) (n=120)
Education:	
Primary	10 (8.3)
High school	19 (15.8)
Higher secondary	14 (11.6)
Graduation	69 (57.5)
Post graduation	7 (5.8)
Doctorate	1 (0.8)
Activity pattern:	
Exercise: A) Yes	62 (51.6)
Daily	30
Weekly	5
<3 times in a week	18
Occasionally	9
B) No	58 (48.3)
Type of exercise:	
Yoga	32 (26.6)
Brisk walking	37 (30.8)
Jogging	6 (5)
Cycling	7 (5.8)
Household work:	
Self	33 (27.5)
Shared with family members	12 (10)
Shared with maid	75 (62.5)
Family monthly income (₹):	
1000-10,000	50 (41.6)
10,000-20,000	36 (30)
20,000-30,000	25 (20.8)
>30,000	9 (7.5)

Note: *Figures in Parenthesis indicate percentages

5.1.2: Anthropometric measurements, prevalence of non-communicable diseases (NCDs) and gastrointestinal (GI) problems

Anthropometric measurements and prevalence of NCDs in Gujarati housewives is shown in Figure 5.1.2.1 and 5.1.2.2 respectively. When compared with Asia Pacific BMI standards, the BMI of the subjects revealed that 54.1% subjects were obese and 17.5% subjects were overweight. Almost 18% subjects suffered from GI problems like acidity and constipation. Amongst the various NCDs reported, diabetes, hypertension, and hypercholesterolemia were prevailed in 7.5, 15.8, and 4.1 per cent subjects respectively.

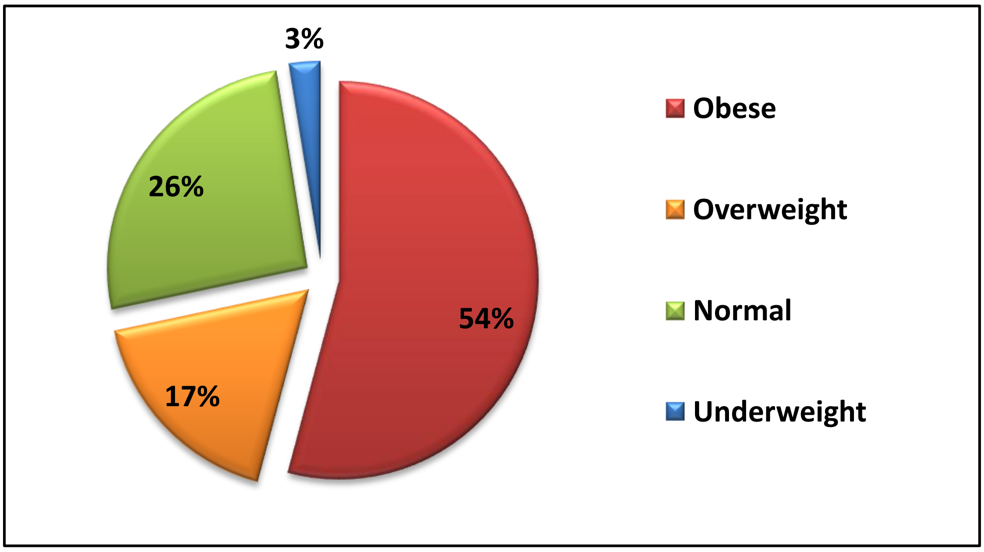


Figure 5.1.2.1: Body mass index classification of Gujarati housewives according to Asia pacific classification

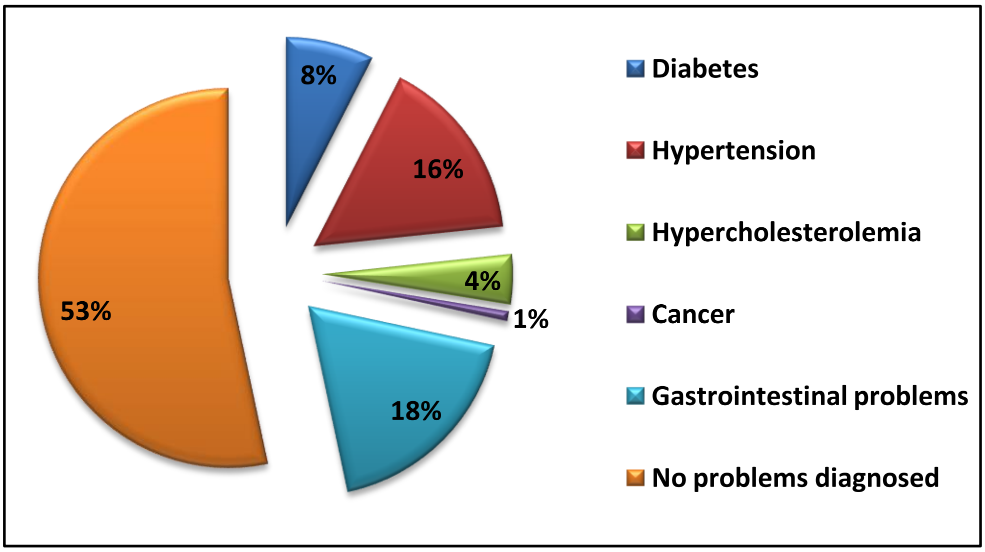


Figure 5.1.2.2: Prevalence of non-communicable diseases and GI problems in Gujarati housewives of urban Vadodara

When the prevalence of NCDs and GI problems of Gujarati housewives was studied for its association with physical activity it was found that obesity and physical activity did not significantly associated at $p<0.05$ level. Similarly, no association was found between physical activity and other co-morbidities at p<0.05 significance level (Table 5.1.2.1).

Table 5.1.2.1: Association between exercise and prevalence of NCDs and GI problems in Gujarati housewives

Exercise	NCDs and GI problems							
	Obesity		Diabetes		Hypertension		GI problems	
	≥25 BMI	<25 BMI	Yes	No	Yes	No	Yes	No
Yes	38	24	3	59	8	54	12	50
No	27	31	6	52	11	47	10	48
Chi-square	χ^2 =2.62^{NS}		χ^2=1.31 ^{NS}		χ^2=0.83 ^{NS}		χ^2=0.09 ^{NS}	
Odds ratio	**1.82**		**0.44**		**0.63**		**1.15**	
CI 95%	**L-0.83; U-4.01**		**L-0.07; U-2.20**		**L-0.20; U-1.90**		**L-0.41; U-3.28**	

Note: NS-non significant; CI-Confidence Interval

Obesity is implicated in several other disorders and therefore needs to be managed effectively. In the present study, obesity showed significant (p<0.05) association and high odds ratio (OR-7.58) with diabetes. However, other co-morbidities showed non-significant association with obesity (Table 5.1.2.2).

Table 5.1.2.2: Association of obesity with other co-morbidities of Gujarati housewives

BMI classification	Hypertension		Diabetes		GI problems	
Obesity	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
≥25 BMI	13	52	8	57	14	51
<25 BMI	6	49	1	54	8	47
Chi-square	χ^2=1.85 ^{NS}		χ^2=4.73*		χ^2=0.97 ^{NS}	
Odds ratio	**2.04**		**7.58**		**1.61**	
CI 95%	**L-0.66; U-7.05**		**L-0.95; U-342. 39**		**L-0.57;U-4.85**	

Note: NS-non significant; *-significant at p<0.05; CI-Confidence Interval

5.1.3: Food habits; preferred cooking method for a meal and its frequency

Figure 5.1.3.1 shows the food habits of Gujarati housewives. It can be seen from the graph that 80% of housewives were vegetarian, 12% ovo-vegetarian and only 8.3% of them were non-vegetarian. The survey revealed that for the preparation of non-vegetarian and ovo-vegetarian foods 90% and 100% housewives preferred shallow fried and deep fried method respectively.

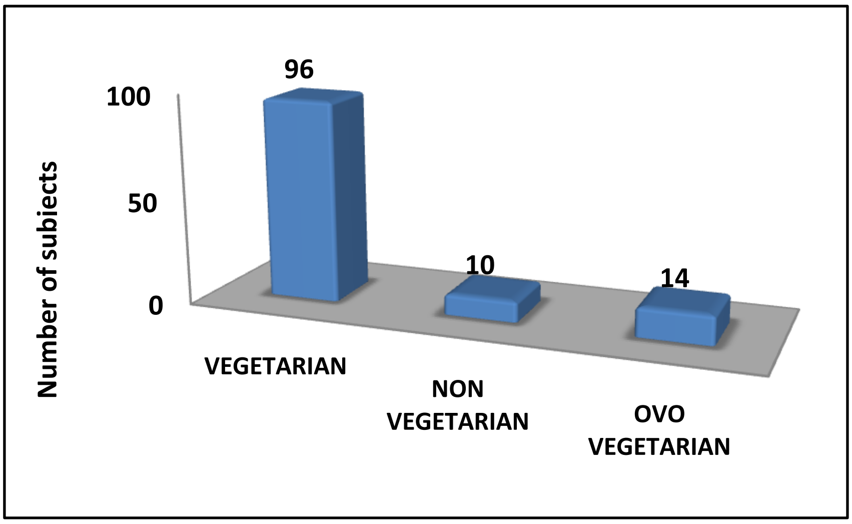


Figure 5.1.3.1: Food habits of Gujarati housewives

Frequency of cooking methods used for preparing a meal is shown in Figure 5.1.3.2. Survey revealed that roasting was used by 92%, sautéing (73%), boiling (51%) and shallow frying (23%) daily for preparing a meal followed by lesser number of subjects using steaming and deep frying daily for cooking purpose. Grilling as a method of cooking was used by only 3% housewives on daily basis. In context to shallow fried and deep fried method used by Gujarati housewives showed that, 24% use these methods 2-3 times a week. Survey also revealed that sautéing was used by 73% of housewives on daily basis for preparing a meal.

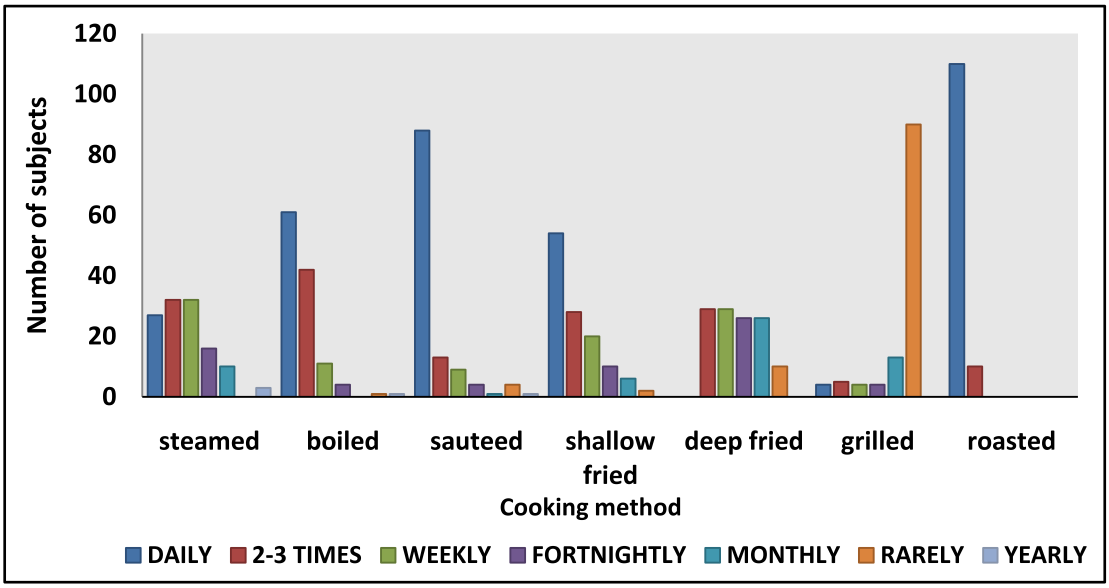


Figure 5.1.3.2: Frequency of cooking methods used for preparing a meal

5.1.4: Consumption pattern of foods prepared at home and its association with prevalence of NCDs and GI problems

Table 5.1.4 shows the consumption pattern of foods prepared at home and its association with prevalence of NCDs and GI problems.

Deep fried foods: Consumption frequency of selected foods by housewives of urban Vadodara revealed that 5% subjects consume deep fried foods daily. 20.8% subjects consumed deep fried foods 2-3 times a week while 55% consumed deep fried foods weekly. In less frequent pattern, 60.8%-82.5% of subjects consumed deep fried foods fortnightly-occasionally. Association between deep fried foods consumption frequency and prevalence of most NCDs was non-significant. However, odds ratio (OR=4.50) showed high association between daily consumption of deep fried food and obesity.

Shallow fried foods: Almost 43% housewives consumed shallow fried foods daily while 30% and 49% housewives consumed shallow fried foods 2-3 times a week and weekly respectively. Significant ($p<0.05$) association and high odds ratio (OR=5.13) was found between daily shallow fried foods consumption and prevalence of diabetes. However, no significant association was found between consumption of shallow fried foods and other co morbidities.

Deep fried sweets: Deep fried sweets were consumed by only 2.5% on weekly basis and 71.6% of housewives consumed occasionally. No association was found between deep fried sweets consumption and prevalence of NCDs in housewives.

Table 5.1.4: Frequency of consumption of deep fried, shallow fried and deep fried sweets prepared at home and its association with the prevalence of NCDs and GI problems in the Gujarati housewives of urban Vadodara

Frequency	Foods	No. of subjects N (%)	Prevalence of NCDs and GI problems											
			Obesity n=65 N (%)	χ^2	OR	Hypertension n=19 N (%)	χ^2	OR	Diabetes n=9 N (%)	χ^2	OR	Gastrointestinal problems n=22 N (%)	χ^2	OR
Daily	**Deep fried §**	6 (5)	5 (7.69)	**2.16^{NS}**	**4.50**	1 (5.2)	-	-	-	-	-	1 (4.54)	-	-
	Shallow fried Ŧ	52(43.3)	32 (49.2)	**2.01^{NS}**	**1.70**	11 (57.8)	**1.95^{NS}**	**2.01**	7 (77.7)	**4.70***	**5.13**	13 (59)	**2.72^{NS}**	**2.19**
	Sweets (deep fried)Ħ	-	-	-	-	-	-	-	-	-	-	-	-	-
2-3 times a week	**Deep fried §**	25 (20.8)	14 (21.5)	**0.04^{NS}**	**1.10**	5 (26.3)	**0.41^{NS}**	**1.45**	-	-	-	6 (27.2)	-	-
	Shallow fried Ŧ	36 (30)	20 (30.7)	**0.04^{NS}**	**1.08**	5 (26.3)	**0.15^{NS}**	**0.81**	1 (11.1)	-	-	6 (27.2)	-	-
	Sweets (deep fried)Ħ	-	-	-	-	-	-	-	-	-	-	-	-	-
Weekly	**Deep fried §**	66 (55)	33 (50.7)	**1.03^{NS}**	**0.69**	13 (68.4)	**1.64^{NS}**	**1.96**	5 (55.5)	**0.00^{NS}**	**1.02**	11 (50)	**0.27^{NS}**	**0.78**
	Shallow fried Ŧ	59 (49.1)	29 (44.6)	**1.18^{NS}**	**0.67**	12 (63.1)	**1.77^{NS}**	**1.97**	3 (33.3)	-	-	12 (54.5)	**0.31^{NS}**	**1.30**
	Sweets (deep fried)Ħ	3 (2.5)	3 (4.6)	-	-	2 (10.5)	-	-	-	-	-	-	-	-
Fortnightly	**Deep fried §**	73 (60.8)	40 (61.5)	**0.03^{NS}**	**1.07**	14 (73.6)	**1.56^{NS}**	**1.99**	7 (77.7)	**1.17^{NS}**	**2.39**	14 (63.6)	**0.09^{NS}**	**1.16**
	Shallow fried Ŧ	53 (44.1)	30 (46.1)	**0.23^{NS}**	**1.19**	10 (52.6)	**0.66^{NS}**	**1.50**	1 (11.1)	-	-	6 (27.2)	-	-
	Sweets (deep fried)Ħ	12 (10)	8 (12.3)	-	-	2 (10.5)	-	-	-	-	-	1 (4.54)	-	-
Monthly	**Deep fried §**	102 (85)	55 (84.6)	**0.02^{NS}**	**0.94**	17 (89.4)	**0.35^{NS}**	**1.60**	9 (100)			18 (81.8)	**0.21^{NS}**	**0.75**
	Shallow fried Ŧ	74 (61.6)	39 (60)	**0.17^{NS}**	**0.86**	11 (57.8)	**0.14^{NS}**	**0.83**	6 (66.6)	**0.10^{NS}**	**1.26**	13 (59)	**0.08^{NS}**	**0.88**
	Sweets (deep fried)Ħ	27 (22.5)	13 (20)	**0.51^{NS}**	**0.73**	4 (21)	-	-	1 (11.1)	-	-	5 (22.7)	-	-
Occasionally	**Deep fried §**	99 (82.5)	51 (78.4)	**0.01^{NS}**	**0.97**	19 (100)	-	-	6 (66.6)	**1.69^{NS}**	**0.39**	18 (81.8)	**0.01^{NS}**	**0.94**
	Shallow fried Ŧ	74 (61.6)	38 (58.4)	**0.62^{NS}**	**0.74**	12 (63.1)	**0.02^{NS}**	**1.08**	6 (66.6)	**0.10^{NS}**	**1.26**	12 (54.5)	**0.58^{NS}**	**0.70**
	Sweets (deep fried)Ħ	86(71.6)	44 (67.6)	**1.10^{NS}**	**0.65**	13 (68.4)	**0.12^{NS}**	**0.83**	6 (66.6)	**0.12^{NS}**	**0.77**	17 (77.2)	**0.42^{NS}**	**1.43**

§- Chips, French fries, Samosa, Cutlet, Breadrolls, Kachori, Bhajia, Vada, Meduvada, Mathri, Namakpara, Chiwda, Chanadal, Moongdal, Puri, Bhatura, Faafda; Ŧ- Bhakri, Pav bhaji, Bhalle, Sev khamni, Burgers, Hotdogs, Cheela; Ħ- Gulabjamun, Jalebi, Mysorepak, Boondi laddo; NS-non significant; *p=<0.05, OR=Odds ratio; Figures in Parenthesis indicate percentages

5.1.5: Consumption pattern of fried foods purchased from market and its association with prevalence of NCDs and GI problems

Table 5.1.5 shows the results of consumption pattern of deep and shallow fried foods purchased from market and its association with prevalence of NCDs and GI problems.

Deep fried foods: Consumption frequency of selected foods purchased by housewives of urban Vadodara showed that only 3 out of 120 subjects consumed deep fried foods daily. Amongst the subjects who subjects purchased deep fried foods daily 2 were not obese. In frequent consumption pattern (2-3 times of week) of fried foods purchased from market, 9 (13.84%) were obese, 2 (10.52%) had hypertension, about 3 (30%) had diabetes and 3 (13.6%) subjects were frequent suffered from gastrointestinal problems. However, chi-square showed no significant association between deep fried food consumption and prevalence of NCDs. 40-70% subjects consumed deep fried foods weekly-fortnightly. Chi-square showed a significant ($p<0.05$) association between gastrointestinal problems and fortnightly consumption of deep fried foods.

Shallow fried foods: Consumption of shallow fried foods was found in 4 (3%) subjects out of whom 3 (4.61%) subjects were obese. Weekly consumption of shallow fried foods was found in 9% subjects. However, no significant association was found in consumption of shallow fried foods and co-morbidities. High odds ratio (OR), 2.18 was found in weekly shallow fried consumption and hypertension. Occasional consumption of shallow fried foods showed a significant ($p<0.05$) association with hypertension.

Deep fried sweets: Consumption of deep fried sweets was found only in 5% subjects on weekly basis. 17% subjects were obese who consumed deep fried sweets monthly. Association between monthly consumption of deep fried sweets and obesity was significant at $p<0.05$ level. Diabetes also showed a significant ($p<0.05$) association with occasional consumption of deep fried sweets.

Table 5.1.5: Frequency of consumption of deep fried, shallow fried and deep fried sweets purchased from market and its association with the prevalence of NCDs and GI problems in the Gujarati housewives of urban Vadodara

Frequency	Foods	No. of subjects N (%)	Prevalence of NCDs and GI problems											
			Obesity n=65 N (%)	χ^2	OR	Hypertension n=19 N (%)	χ^2	OR	Diabetes n=9 N (%)	χ^2	OR	Gastrointestinal problems n=22 N (%)	χ^2	OR
Daily	**Deep fried §**	3 (2.5)	1 (1.53)	-	-	-	-	-	-	-	-	-	-	-
	Shallow fried Ŧ	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sweets (deep fried)Ħ	-	-	-	-	-	-	-	-	-	-	-	-	-
2-3 times a week	**Deep fried §**	15 (12.5)	9 (13.84)	**0.28^{NS}**	**1.35**	2 (10.52)	**0.08^{NS}**	**0.80**	3 (33.33)	**0.03^{NS}**	**0.89**	3 (13.63)	**0.03^{NS}**	**1.13**
	Shallow fried Ŧ	4 (3.33)	3 (4.61)	-	-	-	-	-	-	-	-	1 (4.54)	-	-
	Sweets (deep fried)Ħ	-	-	-	-	-	-	-	-	-	-	-	-	-
Weekly	**Deep fried §**	43(35.83)	22(33.84)	**0.24^{NS}**	**0.83**	6 (31.57)	**0.18^{NS}**	**0.80**	3 (33.33)	**0.03^{NS}**	**0.89**	7 (31.81)	**0.12^{NS}**	**0.84**
	Shallow fried Ŧ	11(9.16)	6 (9.23)	**0.00^{NS}**	**1.02**	3 (15.78)	**1.19^{NS}**	**2.18**	-	-	-	1 (4.54)	-	-
	Sweets (deep fried)Ħ	6 (5)	5 (7.69)	-	-	2 (10.52)	-	-	-	-	-	1 (4.54)	-	-
Fortnightly	**Deep fried §**	49(40.83)	25(38.46)	**0.33^{NS}**	**0.81**	9 (47.36)	**0.40^{NS}**	**1.37**	3 (33.33)	**0.28^{NS}**	**0.68**	5 (22.72)	**3.98***	**0.35**
	Shallow fried Ŧ	24(20)	14(21.53)	**0.21^{NS}**	**1.24**	4 (21.05)	**0.02^{NS}**	**1.08**	3 (33.33)	**0.25^{NS}**	**0.71**	5 (22.72)	**0.13^{NS}**	**1.22**
	Sweets (deep fried)Ħ	9(7.5)	6 (9.23)	**0.61^{NS}**	**1.76**	1 (5.26)	-	-	-	-	-	2 (9.09)	**0.10^{NS}**	**1.30**
Monthly	**Deep fried §**	88(73.33)	44(67.69)	**2.31^{NS}**	**0.52**	15 (78.94)	**0.36^{NS}**	**1.44**	9 (100)	-	-	16 (72.72)	**0.01^{NS}**	**0.96**
	Shallow fried Ŧ	48(40)	25(38.46)	**0.14^{NS}**	**0.87**	10 (52.63)	**1.50^{NS}**	**1.04**	2 (22.22)	**1.28^{NS}**	**0.40**	6 (27.27)	**1.82^{NS}**	**0.50**
	Sweets (deep fried)Ħ	30(25)	11(16.92)	**4.93***	**0.39**	5 (26.31)	**0.02^{NS}**	**1.09**	2 (22.22)	**0.04^{NS}**	**0.85**	5 (22.72)	**0.07^{NS}**	**0.86**
Occasionally	**Deep fried §**	80(25)	42(64.61)	**0.27^{NS}**	**0.82**	13 (68.42)	**0.01^{NS}**	**1.05**	7 (77.77)	**0.54^{NS}**	**1.82**	17 (77.27)	**1.17^{NS}**	**1.81**
	Shallow fried Ŧ	59(49.16)	29(44.61)	**1.18^{NS}**	**0.67**	5 (26.31)	**4.72***	**0.31**	5 (55.55)	**0.16^{NS}**	**1.32**	13 (59.09)	**1.06^{NS}**	**1.63**
	Sweets (deep fried)Ħ	90(7.5)	47(72.30)	**0.55^{NS}**	**0.73**	14 (73.68)	**0.02^{NS}**	**0.92**	4 (44.44)	**4.84***	**0.23**	15 (68.18)	**0.67^{NS}**	**0.66**

§- Chips, French fries, Samosa, Cutlet, Breadrolls, Kachori, Bhajia, Vada, Meduvada, Mathri, Namakpara, Chiwda, Chanadal, Moongdal, Puri, Bhatura, Faafda; Ŧ- Bhakri, Pav bhaji, Bhalle, Sev khamni, Burgers, Hotdogs, Cheela; Ħ- Gulabjamun, Jalebi, Mysorepak, Boondi laddo; NS-non significant; *p=<0.05, OR=Odds ratio; Figures in Parenthesis indicate percentages

5.1.6: Eating out frequency; preferred cooking methods and foods preferred during long distance travelling

Rapid industrialization and change in life styles of people has resulted in marked increase in the consumption of food outside the house. Figure 5.1.6.1 shows the eating out frequency in restaurants/parties of Gujarati housewives. In the present study it was found that more than a quarter per cent (34%) housewives prefer eating out monthly in restaurants/parties. Weekly eating out frequency was observed in more than 20% Gujarati housewives. However, 7% never preferred eating in restaurants or parties.

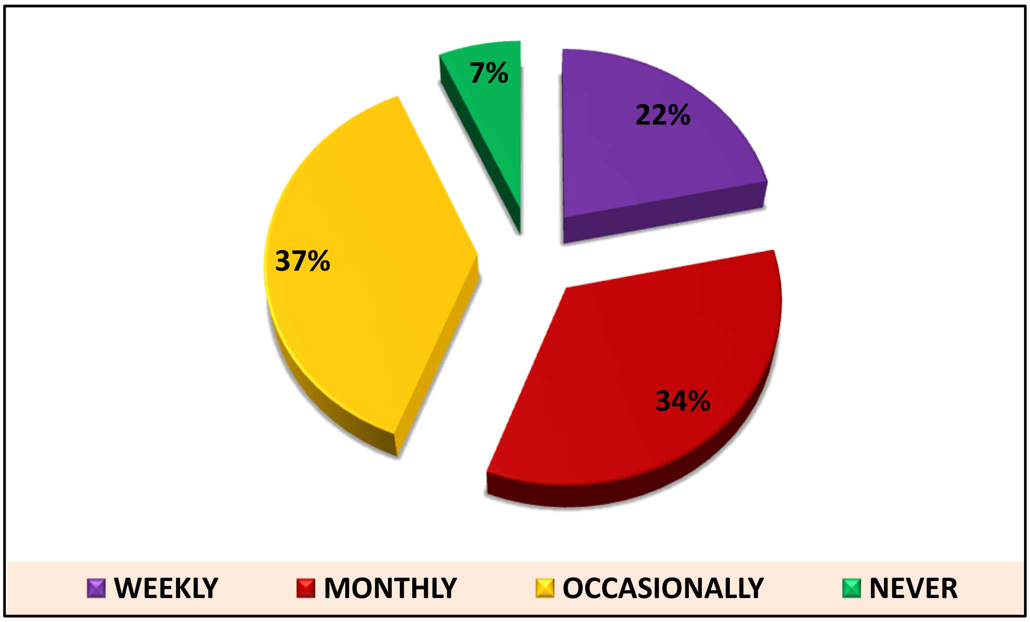


Figure 5.1.6.1: Eating out frequency of Gujarati housewives in parties/ restaurants

Chi-square was applied to find out if any association exists between eating out frequency, prevalence of NCDs and GI problems in Gujarati housewives shown in Table 5.1.6. Weekly, monthly and occasionally eating out frequency showed no significant association between obesity, hypertension, diabetes and GI problems. However, diabetes and GI problems showed high odds ratio of OR 2.60 and 2.27 respectively with monthly eating out frequency.

Table 5.1.6: Association between eating out frequency and prevalence of NCDs and GI problems in Gujarati housewives

Eating out frequency		Prevalence of NCDs and GI problems							
		Obesity		Hypertension		Diabetes		GI problems	
		Yes	No	Yes	No	Yes	No	Yes	No
Weekly	Yes	15	11	6	20	-	-	3	23
	No	50	44	13	81	-	-	19	75
Chi-square		**χ^2=0.17 NS**		**χ^2=1.31 NS**		**-**		**χ^2=1.02 NS**	
Odds ratio		**1.20**		**1.87**		**-**		**0.51**	
CI 95%		**L-0.46;U-3.21**		**L-0.51;U-6.08**		**-**		**L-0.09;U-2.0**	
Monthly	Yes	18	23	5	36	5	36	11	30
	No	47	32	14	65	4	75	11	68
Chi-square		**χ^2=2.64 NS**		**χ^2=0.62 NS**		**χ^2=1.98 NS**		**χ^2=3.00 NS**	
Odds ratio		**0.53**		**0.64**		**2.60**		**2.27**	
CI 95%		**L-0.23;U-1.22**		**L-0.17;U-2.10**		**L-0.52;U-13.83**		**L-0.79;U-6.45**	
Occasio-nally	Yes	26	19	5	40	-	-	6	39
	No	39	36	14	61	-	-	16	59
Chi-square		**χ^2=0.38 NS**		**χ^2=1.20 NS**		**-**		**χ^2=1.20 NS**	
Odds ratio		**1.26**		**0.54**		**-**		**0.57**	
CI 95%		**L-0.56;U-2.85**		**L-0.14;U-1.77**		**-**		**L-0.17;U-1.70**	

Note: NS-non significant; CI-Confidence Interval

Various methods are used for cooking foods stuffs at home and outside home as well. Figure 5.1.6.2 shows the most preferred foods while eating outside home in terms of cooking methods employed.

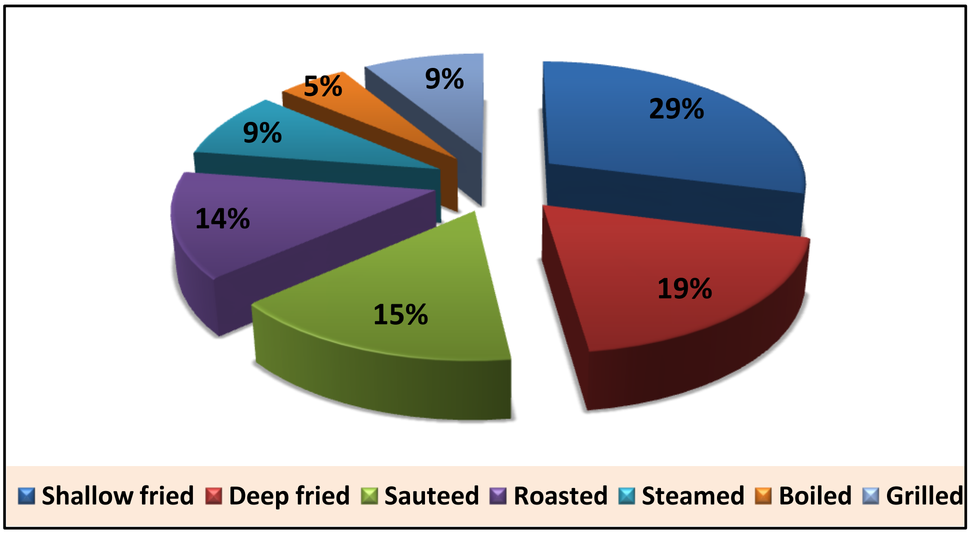


Figure 5.1.6.2: Most preferred food while eating outside

While eating outside most (29%) of the housewives preferred shallow fried foods and 19% housewives preferred deep fried foods. It can be seen that roasted foods were preferred by 14% housewives. Other cooking methods like boiling, grilling and steaming were preferred by 5%, 9% and 9% respectively.

Generally in every part of the world during long distance travelling people take food with them or purchase from the available sources. Here Figure 5.1.6.3 shows the preference of food during long distance travelling of Gujarati housewives. Data shows that most (82%) of the Gujarati housewives prefer homemade food and only 18% prefer ready-to-eat (RTE) foods during long distance travelling.

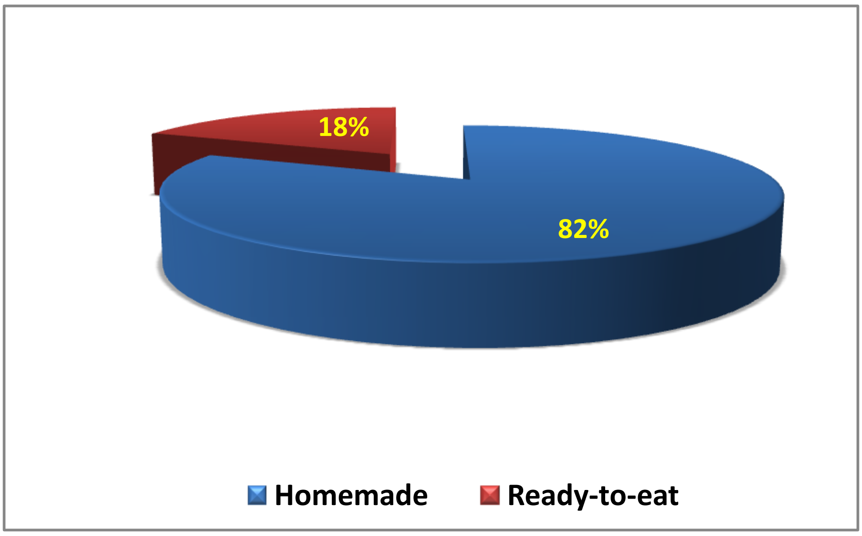


Figure 5.1.6.3: Type of food preferred during long distance travelling

5.1.7: Oil consumption pattern, its use and association with prevalence of NCDs and GI problems

On the basis of oil purchased for household usage, the average monthly per capita intake was calculated as 1.39kg and it ranged from 0.33-5kg. While the daily per capita intake calculated as 40g. As shown in Table 5.1.7.1, 38.3% of Gujarati families use both mono and polyunsaturated rich oil for cooking and nearly 25% of families use only monounsaturated rich oil (groundnut oil). With regards to saturated fats, it was found that 24.1% of families used *vanaspati* for cooking purposes along with other types of saturated fats. Butter was used by about 76% and ghee was used by all the families.

Table 5.1.7.1: Type of oil used by Gujarati housewives for cooking per month in kg (kilogram)

Type of oil used for cooking	
Oil type	**No (%)**
Unsaturated	
Mono+Poly	46 (38)
Mono	29 (24)
Poly	45 (37.5)
Saturated	
Ghee	120 (100)
Butter	91 (75.8)
Vanaspati	29 (24)

Note: Figures in Parenthesis indicate percentages; Mono-monounsaturated; Poly-polyunsaturated

Consumption of *vanaspati* showed a significant ($p<0.001$) association and high odds ratio (OR=4.80) with hypertension as shown in Table 5.1.7.2. However, chi-square showed no significant association with other morbidities and *vanaspati* consumption. Table 5.1.7.3 shows the association between butter consumption and prevalence of NCDs. No significant association was found between butter consumption and prevalence of NCDs and GI problems.

Table 5.1.7.2: *Vanaspati* consumption and its association with prevalence of NCDs and GI problems

***Vanaspati* Consumption**	**Obesity**		**Hypertension**		**Diabetes**		**GI problems**	
	Yes	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Yes	17	12	10	19	4	25	3	26
No	48	43	9	82	5	86	19	72
Chi-square	**χ^2 =0.31^{NS}**		**χ^2 =9.98*****		**χ^2 =2.18 ^{NS}**		**χ^2 =1.63 ^{NS}**	
Odds ratio	**1.27**		**4.80**		**2.75**		**0.44**	
CI 95%	**L-0.50;U-3.27**		**L-1.50;U-15.22**		**L-0.50;U-13.74**		**L-0.08;U-1.68**	

Note: ***-Significant at $p<0.001$; NS-non significant; CI-Confidence Interval

Table 5.1.7.3: Butter consumption and its association with prevalence of NCDs and GI problems

Butter Consumption	Obesity		Hypertension		Diabetes		GI problems	
	Yes	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Yes	47	44	16	75	6	85	18	73
No	18	11	3	26	3	26	4	25
Chi-square	**χ^2=0.96** NS		**χ^2=0.86** NS		**χ^2=0.45** NS		**χ^2=0.53** NS	
Odds ratio	**0.65**		**1.85**		**0.61**		**1.54**	
CI 95%	**L-0.25;U-1.66>**		**L-0.47;U-10.64**		**L-0.12;U-4.06**		**L-0.45;U-6.83**	

Note: NS-non significant; CI-Confidence Interval

Knowledge on oil intake and perception of subjects regarding consequences of excessive fried food intake is shown in Table 5.1.7.4; it was found that 23% of housewives knew correct recommended oil intake/person/day, while rest of the subjects reported low or higher quantities of oil. Almost 40.8% subjects did not know about the recommended daily allowances of oil. Most of housewives reported obesity (11%), heart disease (18%) and both answered obesity and heart disease (29.1%) as consequences of excessive consumption of fried foods. However, 15.8% did not know the consequence of intake of excessive fried foods.

Table 5.1.7.4: Knowledge on daily intake of edible oil by Gujarati housewives and their perception regarding health consequences of excessive fried food intake

Knowledge on amount of oil required/day/person	
Amount of oil required/day/person	**No. (%)**
10-20g	23 (19.17)
20-30g	28 (23.33)
40-60g	15 (12.5)
60-80g	2 (1.67)
No limit	3 (2.5)
Do not know	49 (40.83)
Perception of subjects regarding consequences of consuming excessively fried foods	**No. (%)**
Obesity	14 (11.6)
Heart disease	22 (18.3)
Gastrointestinal problems (GIT)	13 (10.8)
Obesity and heart disease	35 (29.1)
Heart disease and GIT	4 (3.3)
Obesity and GIT	4 (3.3)
Cancer	9 (7.5)
Do not know	19 (15.83)

Note: Figures in Parenthesis indicate percentages

5.1.8: Use of leftover fried oil, containers used for oil storage and practices of storing fried oil

Use of fried oil at household level and its association with their morbidity profile are shown in Table 5.1.8.1 and 5.1.8.2 respectively. It was found that 62.5% of people used leftover fried oil for sautéing vegetables and shortening while 16.7% subjects never used it for refrying purpose. 70.8% of the housewives store oil in steel containers. However, 5% of housewives used other containers like aluminum jars. Occurrence of non-communicable diseases and GI problems did not show any significant association with refrying practices.

Table 5.1.8.1: Use of leftover fried oil and containers use for storage

Use of left over fried oil	No. (%)
Add more fresh oil for refrying	13 (10.8)
Discard frying oil	20 (16.67)
Use fried oil for sautéing vegetable preparations	75 (62.5)
Refry the same oil without adding more	12 (10)
Container for oil storage	
Steel jars	85 (70.83)
Plastic containers (opaque)	17 (14.17)
Aluminum	6 (5)
Plastic transparent jar	8 (6.67)
Glass jars	4 (3.3)

Note: Figures in Parenthesis indicate percentages

Table 5.1.8.2: Association between frying practices and prevalence of NCDs and GI problems in Gujarati housewives

Refrying practice	HT		GI problems		Obesity	
	Yes	No	Yes	No	Yes	No
Not refrying	3	18	3	18	12	9
Refrying	16	83	18	81	53	46
Chi-square	χ^2=0.05[NS]		χ^2=0.18 [NS]		χ^2=0.09 [NS]	
Odds ratio	**0.86**		**0.75**		**1.16**	
CI 95%	**L-0.15;U-3.51**		**L-0.13;U-3.0**		**L-0.40;U-3.41**	

Note: NS-non significant; CI-Confidence Interval

Figure 5.1.8 shows the fried oil storage practices of the subjects revealed that 51.6% of the subjects store the left over fried oil after filtration and 20.8% never stored fried oil.

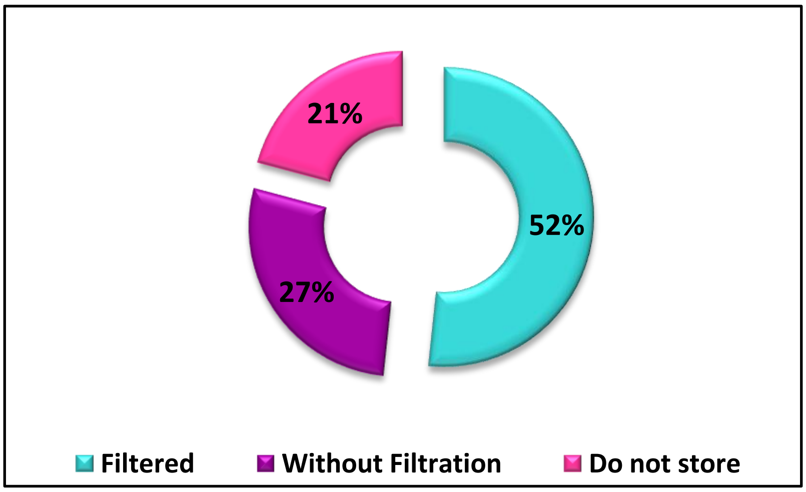


Figure 5.1.8: Practices of housewives for storing fried oil

5.1.9: Knowledge on refrying and filtration of fried oil before storage

As shown in Table 5.1.9, it was found that 58.3% subjects reported that fried oil can be refried and 41.6% subjects do not refry fried oil. However, 20% subjects answered oil should be fried for once only, and 4% said oil can be fried more than 4 times and considered safe for consumption. Knowledge on filtration of fried oil before storage revealed that most housewives (54%) felt that filtration is essential to remove the fried particles and to prevent the changes occurring from the leftover fried particles in oil. 69% of house wives filter fried oil before storage. However, 12.5% subjects believed that filtration is essential to remove dust from the oil.

Table 5.1.9: Knowledge on refrying and filtration of fried oil before storage

Knowledge on refrying	No. (%)
Not to refry	24 (20)
Two times	23 (19.17)
Three times	12 (10)
Four times	6 (5)
More	5 (4.17)
Reasons for filtration of fried oil before storage	**No (%)**
To remove small fried particles	65 (54.17)
To remove dust	15 (12.5)
To clean oil	3 (2.5)

Note: Figures in Parenthesis indicate percentages

5.1.10: Changes observed in fresh oil upon frying and storage of fresh oil

Figure 5.1.10, shows the most common changes noticed in the fried oil were color change (34.1%), thickening (18%) and gumming (9.1%). However, 12.5% never noticed any changes in fried oil. Changes in fresh oil shown in Table 5.1.10 were noticed by only 39% of surveyed housewives and 61% never noticed any change in fresh oil upon long term storage. Moreover, common changes in fresh oil noticed by housewives were color change-11.6%, foul odor-16.7% and thickening of oil-10.8%.

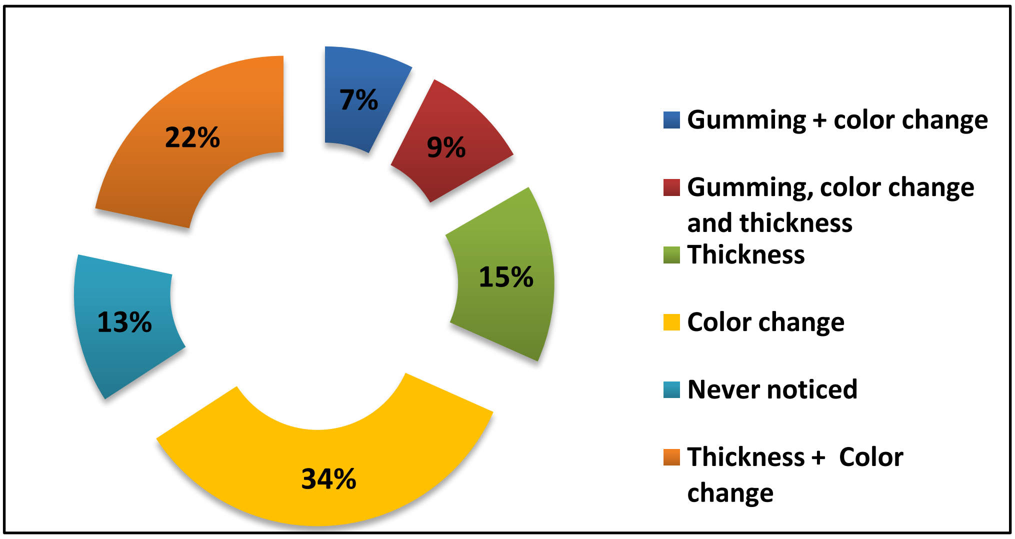


Figure 5.1.10: Changes observed in fresh oil upon frying

Table 5.1.10: Changes observed in fresh oil upon storage of fresh oil

Changes in fresh oil upon long term storage	No. (%)
Change in color	14 (11.67)
Foul odor	20 (16.67)
Thickening of oil	13 (10.83)
Do not notice any change	73 (60.83)

Note: Figures in Parenthesis indicate percentages

5.1.11: Knowledge on oil blends and *trans* fats

Blended oils are good source of essential fatty acids. However, knowledge on blend oils still need to be more popularized. In present study 82.5% of housewives did not know about the oil blends (Figure 5.1.11.1). Moreover, 10.8% housewives answered that oil blends are combination of two or more oils. Knowledge on *trans* fats of Gujarati housewives showed that 24% knew about the *trans* fats (Figure 5.1.11.2).

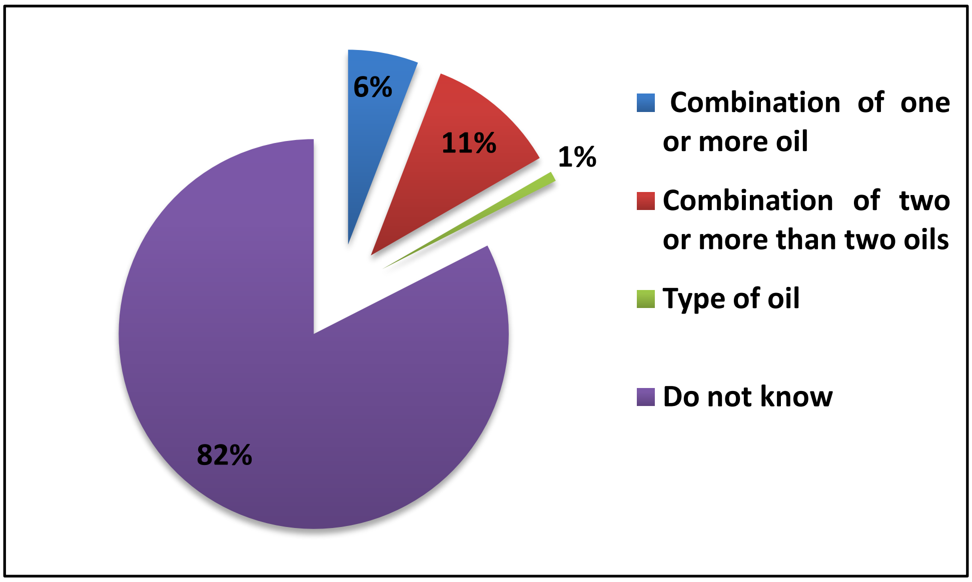


Figure 5.1.11.1: Knowledge on oil blends

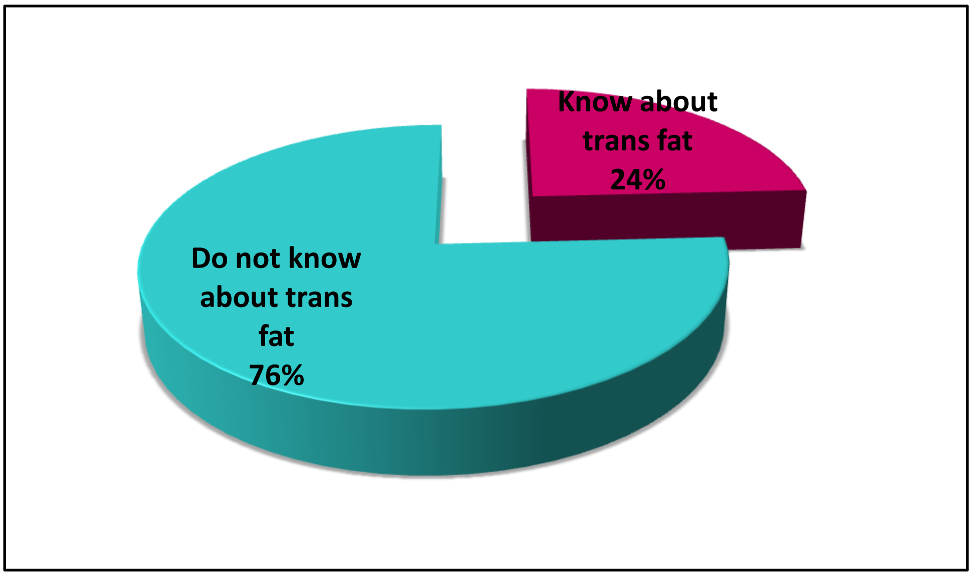


Figure 5.1.11.2: Knowledge on trans fats of Gujarati housewives

Results of the present study showed that, 75.8% housewives did not know about health effects of oil blends, while 13.3% of housewives considered oil blends to be good for health (Table 5.1.11.1).

Table 5.1.11.1: Knowledge on oil blends and *trans* fats of Gujarati housewives

Knowledge on oil blends and their health effects	No (%)
Good for health	16 (13.33)
Not good for health	13 (10.83)
Do not know	91 (75.83)
Knowledge on *trans* fat	**No (%)**
Harmful to health	20 (16.67)
Beneficial to health	3 (2.5)
Adds taste to the diet	4 (3.33)
No effect on health	2 (1.67)
Do not know	91 (75.83)

Note: Figures in Parenthesis indicate percentages

It was found that 75.8% did not know about *trans* fats and its food sources (Table 5.1.11.2). Only 16.6% knew that *trans* fat is a form of fat which is harmful to health. No significant association was observed between the education levels of the subject and knowledge about *trans* fats.

Table 5.1.11.2: Education profile association with knowledge on *trans* fats

Knowledge on trans fat	Primary	High school	Higher secondary	Graduation	Post graduation	Total
Yes	1	2	2	21	3	29
No	9	17	12	48	5	91
Total	10	19	14	69	8	120
Chi-square				$\chi^2=6.02^{NS}$		

Note: NS-non significant

PHASE I - RESULT HIGHLIGHTS

- *The background information regarding the subjects revealed that most of them belong to middle income group and about 71.6% housewives were graduate.*
- *Regarding the fried food consumption pattern deep fried products prepared at home were consumed by 5% of households on daily basis and 55% and 60% households consumed fried foods on a weekly and fortnightly basis. Shallow fried foods were consumed by 43% of households on daily basis and 49% and 44% consumed shallow fried foods weekly and fortnightly basis. None of the households consumed deep fried sweets on daily basis.*
- *Prevalence of obesity was found in 54% of the Gujarati housewives. Other co-morbidities related to obesity such as hypertension and diabetes were present in 16% and 8% housewives respectively. Significant association was seen between diabetes and obesity.*
- *Most of the surveyed subjects were vegetarian and resorted to roasting as most popular cooking method.*
- *Homemade shallow fried foods consumption significantly correlated with diabetes.*
- *Fried food purchased from market fortnightly and its consumption showed a significant association with prevalence of GI problems.*
- *22% Gujarati housewives preferred eating out in restaurants/ parties on a weekly basis and 7% never preferred eating out. However, no association was found between prevalence of NCDs, GI problems and eating out frequency.*
- *Many families reported daily use of saturated fats such as vanaspati (26%), ghee (100%) and butter (76%). Use of vanaspati showed a significant association ($p<0.001$) with prevalence of hypertension. However, consumption of butter did not show association with prevalence of NCDs and GI problems.*
- *Use of leftover fried oil was used for sautéing by most families and no association was found between refrying practices and health ailments.*
- *Very few housewives knew about oil blends and trans fats.*

DISCUSSION

Gujarat is considered as one of the rich and developed states of India. Ethnic Gujarati people are presumed to have high prevalence of Coronary artery disease (CAD) risk factors namely obesity, diabetes, hypertension, dyslipidemia, because of traditional fat and sugar rich Gujarati food and sedentary life style. A study carried out in Gujarat revealed that 61.3% of rural diabetes patients were obese. The female subjects had greater prevalence of obesity (84%) than their male counterparts (58%). Similar trend was seen in urban areas (M: 88%, F: 71%) (Pandya H, Lakhani JD and Patel N, 2011). However, in the present study conducted in urban Vadodara, the rate of prevalence of obesity was lower (54%) than the one cited in the above study. This could possibly be because of the choice of subjects (housewives), who (50%) were engaged in some sort of physical activities such as yoga and brisk walking. Studies have shown that physical activity is significantly associated with reduced rates of obesity (Frank LD, Andresen MA and Schmid TL, 2004). Studies have shown that fried food was positively associated with obesity only among subjects in the highest quintile of energy intake from fried food (Guallar CP et al, 2007). In the present study, high prevalence of obesity (54%) was observed which could be due to frequent consumption of fried and shallow fried foods (2-3 times per week to weekly).

Incidences of obesity and co-morbidities in the present study showed a significant ($p<0.05$) association between obesity and diabetes. These findings are also supported by a recent study conducted in Vadodara region which revealed that almost 70% of diabetic patients were obese. Interestingly authors of the study used “Diabesity” as a synonym for diabetes in Gujarati population (Pandya H, Lakhani JD and Patel N, 2011). Thus, these findings are in accordance with the studies indicating an interrelationship between obesity and diabetes (Misra A and Khurana L, 2008; Qiao Q and Nyamdorj R, 2010; Manimunda SP et al, 2011).

Prevalence of obesity (54%) and hypertension (16%) in present work shows high odds ratio (OR=2.04; 95% confidence limit=7.05, 0.66). A study on prevalence of obesity and hypertension in urban Tamilnadu by Gupta M et al (2011) showed a significant correlation between body weight, BMI and systolic blood pressure. In 2004, it was reported that the average prevalence of hypertension in India was 25% in urban and 10% in rural inhabitants (Gupta R, 2004). Studies carried out on the tribal (Lepchas of Sikkim in Himalayas, tribes of Andhra Pradesh, Gujarat, and Orissa) and labor (Bareilly district-Uttar Pradesh, Gujarat) populations of India documented hypertension prevalence in the range of 15 to 42%, 10.81% and 16.9% respectively. (Manimunda SP et al, 2011; Mahmood SE et al, 2011; Tiwari RR, 2008).

Present study showed 21.5% obesity in Gujarati housewives who consumed deep fried foods 2-3 times a week at home. A study conducted on dietary patterns of adults living in Ouagadougou showed daily consumption of fried and modern foods have positive association (OR=1.11; significant at $p<0.01$) with overweight and fatness (Becquey E et al, 2010). Another study conducted in multicultural society of Mauritius eating practices revealed that 83% urban population do not adhere to the WHO advised guidelines, to consume deep fried and fried foods sparingly (Krige SM et al, 2012).

In the present study, 22 and 34 percent housewives preferred eating out weekly and monthly respectively. In a recent pilot study on Mauritian population revealed that frequency of meals eating out of home, 1-3 times per week was 33.4% for lunch and 26.2% for dinner (Krige SM et al, 2012). Another study on fast foods consumption in young adults (n=341) of Johannesburg revealed 11 per cent participants consume fast foods daily whereas 27.6 per cent consumed fast foods 2-3 times a week (Van Zyl MK, Steyn NP and Marais ML, 2010).

The association between prevalence of NCDs and eating out frequency showed no significant difference. In addition, several researches identified, away from home foods and restaurant meals as a potential cause of obesity

(McCrory MA et al, 1999; French SA, Harnack L and Jeffery RW, 2000), others pointed to the key role of between-meal snacks (Zizza C, Siega-Riz AM and Popkin BM, 2001) and growing portions of foods consumed at home (Drewnowski A and Darmon N, 2005).

In the present study, amongst the most preferred cooking methods during eating outside home, shallow fried was preferred by 63 subjects followed by deep fried (41 subjects). These results show the popularity and preference of fried foods in the surveyed population. Further, the present findings showed consumption of ready-to-eat foods during long distance travelling by 18.3% subjects. In an Indian study, it was found that ready-to-eat foods like fried fries, pizza, burgers were most popular food items consumed by adolescents and young adults in New Delhi (Mahna R, Passi SJ, and Khanna K, 2004). In another study conducted in Johannesburg showed consumption of fast foods namely burgers (69.5%), pizza (56.6%), fries (37%) and fried chicken (36.8%) was popular in interviewed subjects (Van Zyl MK, Steyn NP and Marais ML, 2010). The reason for asking the food preference during long distance travelling is to observe the peoples fondness due to convenience and taste of such foods.

With economic development, and driven by potential economies of scale, super markets tend to replace central food markets, neighborhood stores and street sellers of food in urban areas. Supermarkets are also becoming an emerging force in South Asia, particularly in urban India since the mid-1990s (Pingali P and Khwaja Y, 2004). Report by Pingali P and Khwaja Y (2004) showed that consumption of more energy dense foods and thus, typically, calorie intake has gone up substantially in Asian region particularly in higher income groups. Fried foods contain a considerable amount of fat, and have a negative perceived image due to their high caloric value and increased consumer awareness of the relationship between food, nutrition, and health (Dana D and Saguy IS, 2001).

Present work also focused on understanding the knowledge of Gujarati housewives on changes that take in fried oil, wherein almost 60% housewives did not report of noticing any changes in fried oil. This could possibly be due to their good frying practices as most housewives (90%) rarely reused the fried oil. Ambiguity on the extent of refrying needs to be studied more extensively involving larger population, so that food safety recommendations can be made for profit gaining set ups and at household levels. Frying oil undergoes three main deleterious reactions: oxidation, hydrolysis and thermal decomposition, resulting in the formation of numerous constituents (Dana D and Saguy IS, 2001). Other than chemical changes in fried oil, the main criteria for discontinuing the use of frying oils are color, viscosity and foaming (Ohta S, 1985). Refrying in same oil tends to release some harmful components which may adversely affect health (Crampton EW et al, 1952). The present practice of refrying at household level showed no association with prevalence of NCDs in Gujarati housewives.

Bulletin of the Nutrition Foundation of India reported that fat consumption is higher in prosperous urbanized states like Gujarat, Haryana and Punjab when compared with other States of India (Ramachandran P, 2008). Although results of the present study showed that oil purchased by the Gujarati housewives was within the recommended limits given by NIN. However, much more quantity of oil is likely to be consumed by Gujarati housewives. This does not take into consideration the oil intake from the fried foods purchased from the market. Thus a larger quantity of invisible intake of oil from the purchased fried foods may be the cause for 54% obesity in the present study. Adequate intake of oil may thus be attributed to low prevalence of NCDs except obesity. However, this needs to be validated using a larger sample size.

In this study the housewives did not report changes in stored oil. Storage of fresh oil for longer duration leads to several changes like- color change, foul odor etc (Premavalli KS, Madhura CV, and Arya SS, 1998). In the present survey results showed that maximum housewives stored fresh oil stainless steel containers and plastic jars. Storage of fresh oil in plastic containers and glass jars were practiced by 14% and 3% respectively. Results of few studies have shown that tin plate containers are best for edible oil packaging (Tismis DA, and Karakasides NG, 2002).

The present study throws light on the limited knowledge of the housewives regarding *trans* fats and its sources and no association was found between their education level and their knowledge on *trans* fats. Some investigators have found that in many parts of India, *trans* fat rich hydrogenated vegetable oil (popularly called *vanaspati)* are consumed in greater quantities than in the United States (Willett WC, Ascherio A, 1994; Singh RB et al, 1996). In view of the fact the *trans* fats beyond certain limits are a risk to CVDs, the need for consumer education is a imperative to safeguard the growing prevalence of heart diseases (Sundaram K, 1997; Mozaffarian D, Aro A and Willet WC, 2009).

To conclude, high incidence of obesity with prevalence of other co-morbidities may be attributed to consumption of fats such as ghee on daily basis and frequent intake of fried and shallow fried foods. Most subjects did not have knowledge on recommended daily intake of oils and *trans* fats. Hence education on recommended intakes of oil along with its correct use and blend may perhaps be a good option to reduce overall prevalence of NCDs.

CHAPTER 4

METHODS AND MATERIALS

This chapter deals with the materials and methods used to elicit necessary data on fried food intake by Gujarati housewives and the sensory quality of french fries and bhajias fried in Groundnut and Cottonseed oil intermittently, was studied with respect to various organoleptic attributes and thermal stability of these two commonly used edible oils used for frying french fries and bhajias was assessed with respect to different chemical and physical parameters. Finally the frying practices and other food safety practices of a railway food outlet were also determined. IEC material for safe frying practice was also developed. Various methods used during the course of the study are discussed under the following phases:

PHASE I: **Fried food intake, knowledge on fats and oils and frying practices of the Gujarati housewives of urban Vadodara and its association with the prevalence of NCDs.**

4.1.1 Experimental plan for phase I

4.1.2 Selection of the families

4.1.3 Tool used for collecting data

4.1.4 Statistical analysis

PHASE II: **Sensory qualities of french fries and bhajias fried in cottonseed oil (CSO) and groundnut oil (GNO) during intermittent frying.**

4.2.1 Experimental design of phase II

4.2.2 Screening of panelist for sensory evaluation

4.2.3 Threshold test

4.2.4 Development of score cards for sensory evaluation

4.2.5 Tool used for sensory evaluation

4.2.6 Procurement of oil, potatoes and raw material for french fries and bhajias

4.2.7 Standardization and preparation of french fries and bhajias

4.2.8 Oil uptake by french fries and bhajias during 25 h of intermittent frying

4.2.9 Statistical analysis

PHASE III: Chemical changes due to thermal degradation of intermittently deep fried cottonseed oil (CSO) and groundnut oil (GNO) as a result of french fries and bhajias frying.

4.3.1 Experimental design for phase II

4.3.2 Frying conditions used for french fries and bhajias

4.3.3 Collection of oil samples used for frying french fries and bhajias at intermittent durations

4.3.4 Analysis of CSO and GNO used for frying

4.3.4.1 Chemical methods used to check the quality of CSO and GNO used for frying

a. Fatty acid profile

b. Total polar components

c. Peroxide value

d. p-anisidine value

e. Totox value

f. Iodine value

g. Acid value

4.3.4.2 Physical parameters used to check the quality of CSO and GNO used for frying

a. Refractive Index

b. Color

4.3.5 Statistical Analysis

PHASE IV: Case study on prevailing food safety and frying practices in Jan aahar- a government run food outlet at Vadodara railway station.

4.4.1 To determine the current knowledge of kitchen staff on food safety practices in terms of personal hygiene, food hygiene, environmental hygiene, nutrition and health.

4.4.2 To determine the oil procurement and storage practices and frying practices of kitchen staff working at Jan aahar –a Government run food outlet at Vadodara railway station.

PHASE V: Development of Nutrition Health Education (NHE) material in two languages on intake of edible oil, types, and on choices of oils for healthy living and problems during frying of edible oil and its storage.

4.5.1 To develop IEC material on intake of edible oil, types, and on choices of oils for healthy living.

4.5.2 To develop IEC material on frying and problems during frying.

PHASE I

4.1 Fried food intake, knowledge on fats and oils and frying practices of the Gujarati housewives of urban Vadodara and its association with the prevalence of non-communicable diseases (NCDs).

Frequent/high oil or fried food intake are implicated as one of the reasons for increased prevalence of obesity, diabetes and CHDs across the world. In present phase of the study, Gujarati housewives were surveyed for their fried food intake, knowledge on fats and oils and frying practices and to assess its association with prevalence of non-communicable diseases. Under the survey methods-selection of families, tools used for collecting information are discussed and the use of statistical analysis applied on the obtained data. The study was approved by Medical Ethical Committee under the reference no. F.C.Sc./FND/HE/88.

4.1.1 Experimental plan for phase I

- 120 Gujarati housewives- 30-65 years of age were randomly selected from five different zones of Baroda (Central, North, East, West and South). Baseline information was collected on family monthly income, education level and exercise pattern as well as their knowledge on fats and its use.
- Morbidity profile of housewives was collected to determine the presence of common NCDs and gastrointestinal problem.
- Association between fried food intake and morbidity profile was determined using chi-square and odds ratio.
- Knowledge on amount of oil intake, refrying, changes during storage of fresh, *trans* fats and oil blends was determined using semi-structured questionnaire.

4.1.2 Selection of the families

Using purposive sampling method, one hundred and twenty Guajarati house wives in the age group of 30-65 years belonging to middle income group (Kuppuswamy, 2007) were surveyed from five different zones (Central, North, East, West and South) of urban Vadodara.

4.1.3 Tool used for collecting data

In total 54 questions were asked relating to the general information on various aspects such as education level, exercise, morbidity profile, and specific information on type of oil used for cooking was collected using a pre-tested structured questionnaire (Appendix 11.1). The questionnaire was specifically aimed at collecting information on the consumption pattern of popularly consumed deep fried, shallow fried and sweets prepared at home and purchased from the markets of Vadodara. Frequency of consumption of these foods was determined using a food frequency questionnaire (Appendix 11.1).

Anthropometric measurements were determined by measuring the body weight using calibrated bathroom weighing scale and height was measured using a flexi tape. BMI (Body Mass Index) was calculated using the standard formula (WHO, 2004; Sheth M and Shah N, 2008):

$$\mathbf{BMI} = \frac{\mathbf{Weight\ (kg)}}{\mathbf{Height\ (mt^2)}}$$

4.1.4 Statistical analysis

Statistical analysis was performed using Epi info-2006 and Microsoft Excel-2007. Chi square test and Odds ratio used to determine the association between frequency of deep and shallow fried food and deep fried sweets intake and prevalence of NCDs and GI problems. Association between the knowledge level on *trans* fats and education level of the subjects was also determined using chi square test.

PHASE II

4.2 Sensory qualities of french fries and bhajias fried in Cottonseed oil (CSO) and Groundnut oil (GNO) during intermittent frying.

Sensory evaluation can be defined as scientific method used to analyze and interpret the quality of a food product perceived through the senses of sight, smell, touch taste and hearing (Srilakshmi B, 2004). Frying of foods has unique sensory properties of color, flavor, texture, and palatability.

This phase of the study was conducted to assess the changes occur in sensory quality of fried foods during intermittent frying in CSO and GNO. Intermittent frying can be defined as frying of a food product at predicted time interval. The experimental design of phase 2 is depicted in Figure 4.2.1.

4.2.1 Experimental design for phase II

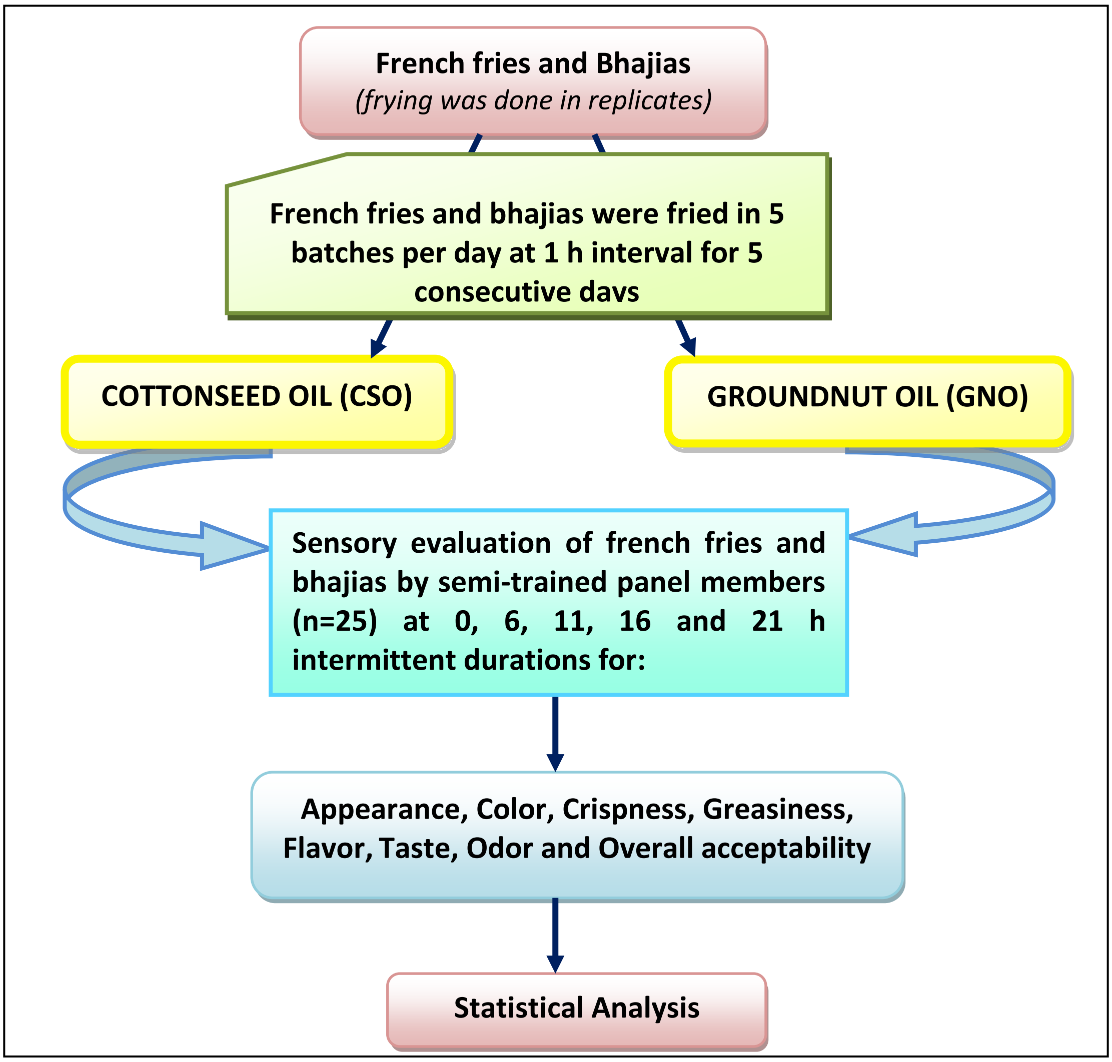


Figure 4.2.1: Experimental design for phase II

4.2.2 Screening of panelists

In this section, selection of panel members was carried out. Students and staff of Department of Foods and Nutrition were subjected to threshold testing.

4.2.3 Threshold test

Threshold is defined as a stimulus scale at which a transition in a series or judgment occurs. For conducting this test, score card for the same was formulated and pre tested (Appendix 11.2). Each perspective panel member was given two sets of the solution i.e. Set 1 and Set 2 having six solutions of different concentrations of salt and sugar respectively and was arranged in random order (Joshi VK, 2006). The participants were asked to identify and rank the samples in increasing order of concentration of taste from the test solutions offered. Three successive trails were conducted for screening of the panelists.

4.2.4 Development of score cards for sensory evaluation of french fries and bhajias

Score cards were developed for sensory evaluation (Appendix 11.3) where in tools for evaluation is listed.

4.2.5 Tool used for sensory evaluation

Hedonic rating scale was used to determine the acceptability of fried foods. It is ascertained for 'likes' and 'dislikes' of foods. Scales with different range of scores or with suitable terms expressing the interest of pleasure can be used (Joshi VK, 2006).

Sensory evaluation of french fries and bhajias were carried out at 0, 6, 11, 16 and 21 h of intermittent frying, without replenishing the oil. Twenty five semi-trained sensory panelists who were familiar with the quality of french fries and bhajias were selected. Freshly fried (hot) french fries and bhajias were judged for appearance, color, crispness, greasiness, taste, flavor, odor, and overall acceptability. French fries and bhajias were evaluated on 9-point hedonic scale where, 9-like extremely, 8-like very much, 7-like moderately, 6-like slightly, 5-neither like nor dislike, 4- dislike slightly, 3-dislike moderately, 2-dislike very much, 1-dislike extremely (Joshi VK, 2006).

4.2.6 Procurement of oil, potatoes and raw material for french fries and bhajias

One month old double filtered groundnut oil (GNO) and refined cottonseed oil (CSO) procured from Ankur Oil Industries (Ahmedabad).

For the preparation of **French fries**, *Kufri surya* variety of potatoes were selected and procured from Potato Research Station, Deesa (Gujarat). This variety is widely used by food chains for the preparation of French fries as it is known to have good frying quality.

For the preparation of **Bhajias** bengal gram flour (*Gaaya brand*) and other ingredients like sodium bicarbonate (Tata), salt (Tata), turmeric powder, red chilli powder and bishop seeds were purchased from local market. Potatoes were procured from potato research station located at, Deesa, Gujarat.

4.2.7 Standardization and preparation of french fries and bhajias

French fries were prepared using similar size of potatoes selected and washed under running water, peeled and sliced in 7×1×1 cm dimension using a stainless steel knife and the excess moisture was removed by spreading them on paper napkins before frying. Raw potato slices were fried in cottonseed oil (CSO) and groundnut oil (GNO) for 5 minutes.

Bhajias were prepared by deep frying thinly sliced circular potatoes that were dipped in a batter prepared out of 75 g Bengal gram flour with 70 ml water, a pinch of sodium bicarbonate, salt, turmeric powder, red chilli powder and bishop seeds were added to the batter (Pasricha S, 2004). Bhajias were fried in cottonseed oil (CSO) and groundnut oil (GNO) for 5 minutes.

4.2.8 Oil uptake by french fries and bhajias during 25 h of intermittent frying

Oil uptake was measured by taking difference between the initial amount of oil used for frying french fries and bhajias in CSO and GNO and total amount of oil left after 25 h of intermittent frying.

Oil uptake= Initial amount of oil-Total oil left in fryer after 25 h of intermittent frying.

4.2.9 Statistical analysis

Mean and standard deviation of values obtained by conducting the experiments in replicate was calculated using Microsoft Excel 2007. Analysis of variance (ANOVA) was used to determine significant difference amongst the french fries and bhajias sensory attributes at intermittent intervals of frying. Student't' test was used to find the significant difference between the two means. Pearson's coefficient was used to calculate correlation between flavor, taste, odor and overall acceptability of french fries and bhajias.

PHASE III:

4.3 Chemical changes due to thermal degradation of intermittently deep fried Cottonseed oil (CSO) and Groundnut oil (GNO) as a result of french fries and bhajias frying.

During deep-frying, thermal, oxidative, and hydrolytic reactions take place and, thus results in physical and chemical changes in the oil or fat consequence of the formation of new compounds. Repeated frying in same oil brings some undesirable modifications in the frying medium. Foods fried in these oils absorb this fat or oil of variable degradation, which contributes considerably to the quality of the dietary fat. Consumption of foods prepared in such oils is responsible for various health ailments.

This phase of the study was designed to study the changes in chemical and physical properties of two dominate oils of Gujarat. The experimental design of this phase is presented in Figure 4.3.1.

4.3.1: Experimental design for phase III

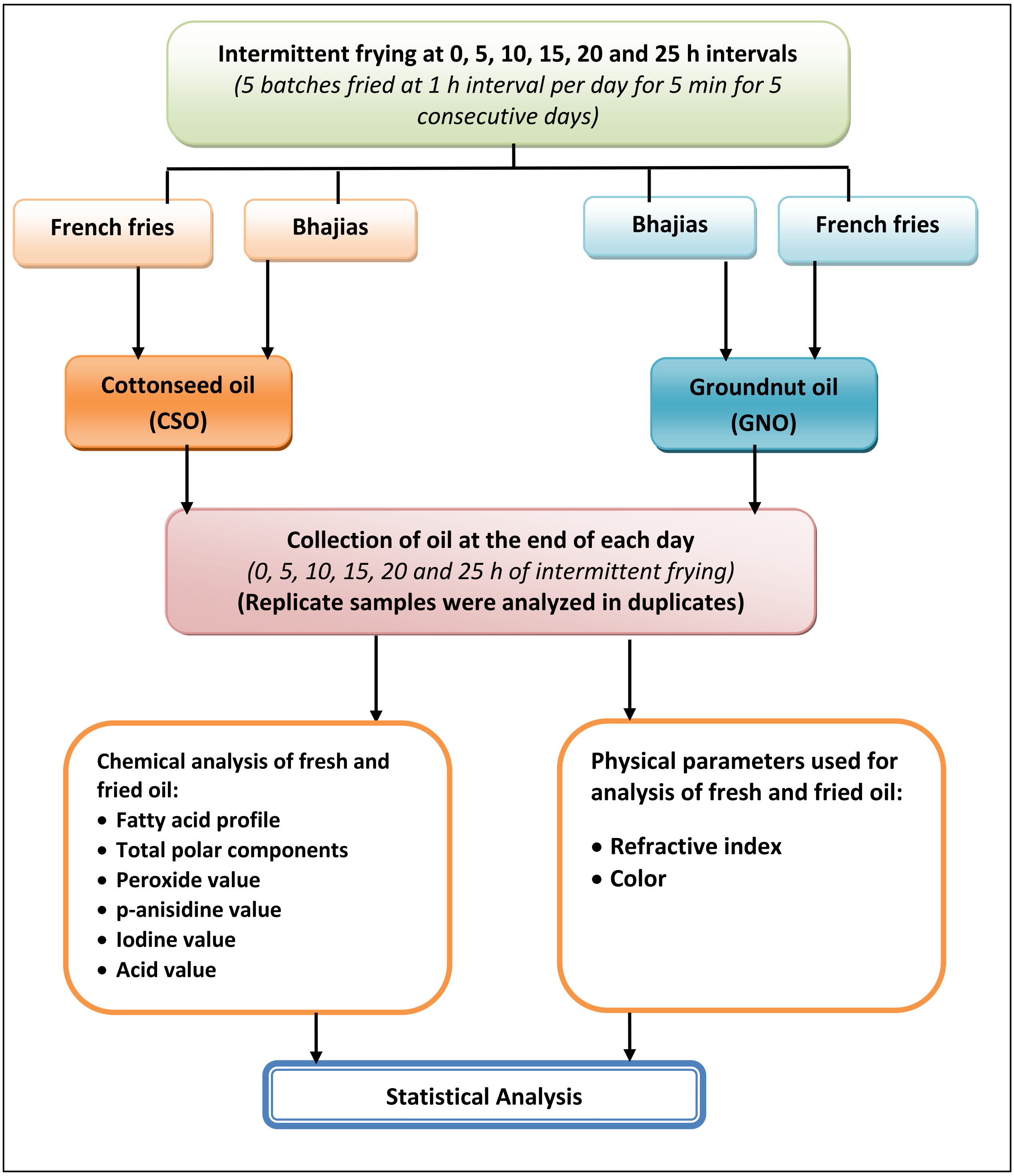


Figure 4.3.1: Experimental design for phase III

4.3.2 Frying conditions used for frying french fries and bhajias

Frying experiment was performed in replicates. Frying was conducted in 2L capacity hindalium domestic frying pan (diameter-12″, depth- 7.2″). Mitsubishi (ISI) mark auto ignition stainless steel LPG stove was used during entire frying experiments. 1.5L GNO was placed in a frying pan and heated between 160^0-180^0C for frying. French fries were dipped in oil at 160^0C and then the temperature was raised to 180^0C. This helped in avoiding french fries from excess browning and aided in restricting cooking time within 5 min. A batch of 170g sliced raw potatoes for french fries and 200g of batter coated potatoes for bhajias were fried in separate oil for 5 min at an interval of 1 h; five times a day for 5 consecutive days. The frying temperature was monitored every minute with the help of mercury thermometer. Frying pan was not covered during the frying operation. The fried oil was not replenished during or post frying. French fries fried oils were not filtered at any interval of frying. Oils used for frying bhajias were filtered at the end of each day to remove the fried debris.

Table 4.3.2.1 and 4.3.2.2 shows the summary of frying operation used for frying french fries and bhajias in CSO and GNO.

Table 4.3.2.1: Frying operation variables for french fries

Frying variables	Oils	
	Cottonseed oil (CSO)	Groundnut oil (GNO)
Food type	Potatoes	Potatoes
Frying vessel	Domestic fryer	Domestic fryer
Total oil quantity (L)	1.5	1.5
Proportion of food to frying oil (g/batch)	170±5	170±5
Temperature (^{0}C)	160-180	160-180
Frying time/batch (min).	5	5
Total frying time (h)	2.5	2.5
Number of frying times	25 intermittent batches of five frying days	25 intermittent batches of five frying days
Total amount of food fried (kg)	4.250	4.250

Table 4.3.2.2: Frying operation variables for bhajias

Frying variables	Oils	
	Cottonseed oil (CSO)	**Groundnut oil (GNO)**
Food type	Bengal gram coated potatoes	Bengal gram coated potatoes
Frying vessel	Domestic fryer	Domestic fryer
Total oil quantity (L)	1.5	1.5
Proportion of food to frying oil (g/batch)	200±5	200±5
Temperature (^{0}C)	160-180	160-180
Frying time/batch (min).	5	5
Total frying time (h)	2.5	2.5
Number of frying times	25 intermittent batches of five frying days	25 intermittent batches of five frying days
Total amount of food fried (kg)	5.0	5.0

4.3.3 Collection of oil samples used for frying french fries and bhajias at intermittent durations

At the end of each day an aliquot of cooled 75ml oil was pipetted out from the pan and stored in amber colored air tight glass bottles (Plate 4.3.3). The fried oil samples collected at the end of each day for 5 consecutive days were kept in a deep freezer for further chemical analysis for peroxide, p-anisidine, Iodine, and Acid value as well as color and refractive index determination.

Plate 4.3.3: Amber color glass bottles used for collection of fried oil samples

4.3.4 Analysis of CSO and GNO used for frying

4.3.4.1 Chemical methods used to check the quality of CSO and GNO used for frying

4.3.4.1.1: <u>Fatty acid profile</u>

Methyl esters of fatty acid (MEFA) were prepared according to AOCS Ce 2-66 method, 1974.

Fatty acid composition was determined using Gas Chromatography (GC) (Perkin Elmer, US) with auto system column PE-FF-AP (30m×0.25μm×0.25mm), a flame ionization detector (FID), and nitrogen as the carrier gas (10psi). GC split ratio was 1:70. The oven temperature was adjusted to 80^0C and held for 2 min. Thereafter, the temperature was raised to 220^0C at the rate of 10^0C per min and held for 10 min. Injector and FID temperature was kept at 250^0C. Standard MEFA were used as authentic samples and peak identification was done by comparing the relative retention times.

4.3.4.1.2: <u>Total polar components</u>

Total polar components were determined by AOAC method 982.27, 1995.

4.3.4.1.2.1 Principle

Total polar component method assesses deterioration of used frying fats, and it's applicable to all fats and oils. Polar components are those components of fats determined by column chromatography under specified conditions and include polar substances such as monoglycerides, diglycerides, free fatty acids that occur in unused fats, as well as polar transformation products formed during frying of food stuffs and/or during heating. Non-polar components are mostly altered triglycerides. Frying fats are separated by column chromatography on silica gel into non polar components. Polar components are determined indirectly by subtracting concentration of non polar components. Quality of separation can be checked by thin layer chromatography.

4.3.4.1.2.2 Preparation of Reagents

1. *Adsorbent*: Silica gel 60, particle size 0.063-0.200mm (70-230 mesh ASTM). Silica gel was dried ≥ 4 h in porcelain dish at 160^0 C in an oven and cool in desiccator to room temperature.

2. *Eluting solvent mixture*: 100ml petroleum ether (bp $40\text{-}60^0$) and ether mixture was prepared by adding 87ml petroleum ether and 13ml ether.

3. Sea sand (analytical reagent grade) was purified by acid and calcined

4. *Spray reagent*: 10% molybdophosphoric acid was prepared in alcohol.

4.3.4.1.2.3 Preparation of sample

Samples were heated to temperature slightly above melting point and mix thoroughly. Visible impurities were removed by filtration.

4.3.4.1.2.4 Preparation of column

1. Column was filled with 30 ml petroleum ether-ether (87+13). Cotton wool wad was placed in the bottom of column and air was removed by pressing with glass rod.

2. 25g silica gel slurry was prepared in 100ml glass beaker by adding approximately 80 ml petroleum ether-ether (87+13). This slurry was poured into column through 8cm glass funnel (Plate 4.3.4.1.2.4).

3. Beaker, funnel, and sides of column were rinsed with same solvent.

4. Solvent was drained to 10cm above silica gel by opening the stopcock and silica gel was leveled by tapping the column.

5. 4g sea sand was added into column and solvent was drained to sand layer.

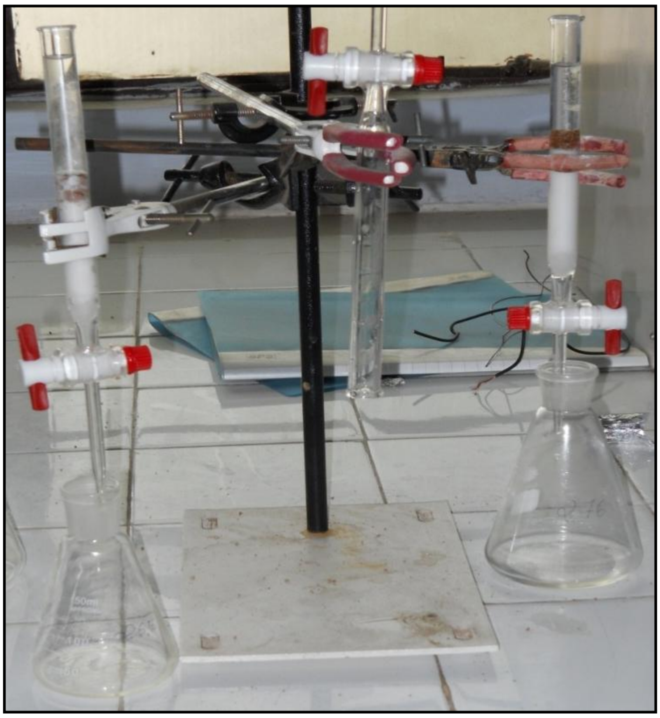


Plate 4.3.4.1.2.4: Preparation of column chromatograph for determination of total polar components in fried oils.

4.3.4.1.2.5 Procedure

1. Polar components were determined by difference, only non polar fraction was used. Both polar and non-polar fractions were required for calculations.

2. Samples were accurately weighed 2.5±0.1g into 50ml volumetric flask, and dissolved in approximately 20ml petroleum ether-ether while warming slightly. After that samples were allowed to cool at room temperature and dilute to volume with same solvent.

3. 20ml sample aliquot was pipette and transferred using volumetric column, without disturbing surface.

4. Two 250ml round-bottom flask were dried at 103±2^{0}C oven, cool to room temperature, and accurately weigh to 0.001g. One flask was placed under column and allows sample solution to drain to level of sand layer by opening stopcock.

5. Non polar components were eluted with 150ml petroleum ether-ether contained in 250ml dropping funnel. Flow rate was adjusted so that 150ml passes through column within 60-70 minute. After elution, any substance adhering to outlet of column into round-bottom flask was washed with petroleum ether-ether (87+13).

6. Polar components were eluted into second 250ml round-bottom flask with 150ml ether. Silica gel was discarded after elution of one sample.

7. Solvent from each fraction were removed with an evaporator and $\leq 60^0$ water bath.

8. Residues were allowed to cool at ambient temperature and then flasks were weighed.

4.3.4.1.2.6 Thin layer chromatography to check efficiency of column chromatography

1. Polar and non-polar fraction (1+9) diluted in $CHCl_3$.

2. 2µl spots were applied using capillary dispensing pipette. Thin layer chromatograph was developed with petroleum ether-ether-CH_3COOH (70+30+20) in tank lined with filter paper for approximately 35 min (17 cm).

3. Plate was removed from tank and allowed solvent to evaporate. Plate was kept in iodine chamber. After evaporation of alcohol, heat plate at 120-130^{0}C in drying oven. Fraction 1(non polar) should be free of polar substances (Plate 4.3.4.1.2.6).

Plate 4.3.4.1.2.6: Thin layer chromatograph sheet for separation of polar and non-polar components in fried oils

4.3.4.1.2.7 Calculation

Polar components were calculated as % (wt/volume) by formula-

Polar components; %= [(E-A)/E] X 100

Where, A= g non polar fraction

E= g sample in 20ml aliquot (approximately 1g)

(Results were reported to 1 decimal place)

4.3.4.1.3: <u>Peroxide value</u>

Peroxide value of oils used for frying was assessed by AOAC method 965.33, 1995.

4.3.4.1.3.1 Principle

Peroxide value is commonly used as an indicator to measure peroxides of the early stages of oxidation in fats and oils. The peroxides present are determined by titration against sodium thiosulphate in the presence of potassium iodide. Starch is used as indicator.

In oxidative rancidity oxygen is taken up by the fat with the formation of peroxides. The degree of peroxide formation and the time taken for the development of rancidity differ among oils.

4.3.4.1.3.2 Preparation of reagents

1. *Acetic acid-chloroform solvent mixture (3:2):* 3 volumes of glacial acetic acid were mixed with 2 volumes of chloroform.

2. *Saturated potassium iodide (KI) solution*: Saturated potassium iodide solution was prepared in water. Potassium iodide was added to water till it stops dissolving in water.

3. *0.1 N Sodium thiosulphate* ($Na_2S_2O_3$) *solution:* 25g of sodium thiosulphate was weighed and dissolved in 1L of distilled water. Solution was boiled, cooled and filtered in 1000ml volumetric flask. Sodium thiosulphate solution was standardized against standard potassium dichromate solution.

4. *1% Starch solution*: 1g starch was weighed and mixed in 100ml lukewarm distilled water with continuous stirring.

4.3.4.1.3.3 Procedure

1. 5 ± 0.5g sample was weighed into a 250ml stopper conical flask.

2. 30ml acetic acid-chloroform solvent mixture was added to weighed sample and swirl to dissolve.

3. 0.5ml saturated KI solution was added add with a pipette. KI added sample was allowed to stand for 1 min in dark with occasional shaking, and then 30ml of water was added.

4. 0.1 N sodium thiosulphate was filled in 25ml burette. Sodium thiosulphate solution was slowly titrated to the liberated iodine solution, with vigorous shaking until yellow color was almost gone (Plate 4.3.4.1.3.3).

5. 0.5ml starch solution was added as indicator and titration was continued by shaking vigorously to release all iodine from $CHCl_3$ layer until blue color disappears.

6. One blank was conducted with each sample determination.

(When less than 0.5ml of 0.1 N $Na_2S_2O_3$ was used during titration, sample was repeated using 0.01 N $Na_2S_2O_3$).

4.3.4.1.3.4 Calculation

Peroxide value expressed as mili equivalent of peroxide oxygen per kg sample (meq/kg)

$$\textbf{Peroxide value} = \frac{\textbf{Titre X N X 100}}{\textbf{Weight of the sample}}$$

Where, Titre = ml of Sodium thiosulphate used (blank corrected)

N = Normality of sodium thiosulphate solution

Plate 4.3.4.1.3.3: Determination of peroxide value by titration method

4.3.4.1.4: **<u>p-anisidine value</u>**

AOCS Cd 18-90 method (1998) was used to determine the p-anisidine value of oils. This method defined as 100 times the optical density measured at 350 nm in a 1cm cell containing 1g of oil in 100ml of mixture of solvent and reagent is used to determine the secondary changes in oils.

4.3.4.1.4.1 Principle

Secondary oxidation products were measured by determining the p-anisidine value. Aldehydic compounds in fats and oils react with p-anisidine, in the presence of acetic acid, to form yellowish reaction products. According to the method the intensity of the yellowish compounds is not related only to the amount of aldehydic compounds present, but also to their structure. A double bond in the carbon chain conjugated with the carbonyl double bond increases the molar absorbance four to five times. p-anisidine determines the quantity of aldehydes (principally 2-alkenals and 2,4-dienals) present in oils and fats.

4.3.4.1.4.2 Preparation of reagents

1. *Isooctane (2,2,4-trimethylpentane)* or *n-hexane*: Analytical grade n-hexane reagent was purchased from authenticated chemical dealer.

2. *p-anisidine (analytical reagent quality):* 0.25g p-anisidine was mixed in 100ml glacial acetic acid.

4.3.4.1.4.3 Procedure

1. 0.5–4.0 ± 0.001g of sample was weighed into a 25ml volumetric flask. Dissolved and diluted to volume with isooctane (Plate 4.3.4.1.4.3.1).

2. Absorbance (Ab) of the solution was measured at 350nm in a cuvette with the spectrophotometer (Shimadzu UV-VIS spectrophotometer 1201) shown in Plate 4.3.4.1.4.3.2, using the reference cuvette filled with solvent as a blank.

3. Exactly 5ml of the fat solution was pipette into one test tube and exactly 5 ml of the solvent into a second test tube. By means of a pipette, exactly 1ml of the solvent was added into a second test tube (Plate 4.3.4.1.4.3.3). By means of a pipette, exactly ml of the p-anisidine reagent was added to each tube, and shake.

Plate 4.3.4.1.4.3.1: Dilution of oil sample with isooctane in 25 ml volumetric flask

4. After exactly 10 min, solvent in the first test tube was filled in the cuvette and absorbance (As) was measured at 350nm, using the p-anisidine solution from the second test tube as a blank in the reference cuvette.

Plate 4.3.4.1.4.3.2: Shimadzu UV-1201 used for determination of p-anisidine value

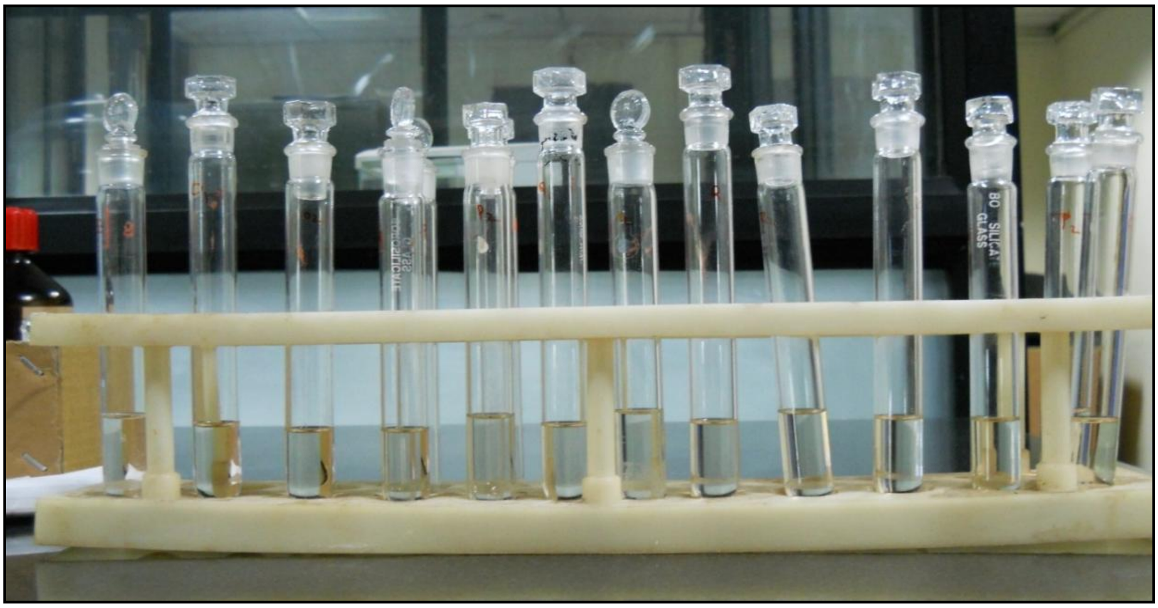


Plate 4.3.4.1.4.3.3: Addition of p-anisidine reagent in diluted samples of oils for second absorbance (As)

4.3.4.1.4.4 Calculation

The p-anisidine value (p-AnV) is given by the formula

$$\textbf{p-AnV} = \frac{25 \times (1.2\ As - Ab)}{m}$$

Where,

As = absorbance of the fat solution after reaction with the p-anisidine reagent

Ab = absorbance of the fat solution

m = mass of the test portion in grams

4.3.4.1.5: Totox value

The TOTOX (i.e. total oxidation products) value was calculated by AOCS Cc13e-92 method. The TOTOX value was calculated as:

TV=2 peroxide value + p-anisidine value

4.3.4.1.6: Iodine value

Iodine value was determined by AOAC 993.20 Wij's method, 1995.

4.3.4.1.6.1 Principle

Fat or oil sample is mixed with iodine monochloride solution to halogenate double bonds in fat or oil. Excess iodine monochloride is reduced to free iodine in presence of potassium iodide, and free iodine is measured by titration with sodium thiosulphate ($Na_2S_2O_3$) using starch as indicator. Iodine value, calculated as approximate iodine absorbed per g of sample (% iodine absorbed), is a measure of unsaturation of fats and oils.

4.3.4.1.6.2 Preparation of reagents

1. *15% potassium iodide (KI) solution*: 15g KI dissolved in 100ml distill water.

2. *Wij's iodine solution*: 13g iodine was dissolved in 1L acetic acid, and passed in dried (through H_2SO_4) Cl until original $Na_2S_2O_3$ titration of solution was not quite doubled. (Characteristic color change at end point indicated

proper amount of Cl. Convenient method is to reserve some of original iodine solution, add slight excess of Cl to bulk of solution, and bring to desired titer by re-additions of reserved portion). Wij's solution is sensitive to temperature, moisture and light. Solution was stored in amber color bottle in dark at <30^0C.

3. *Soluble starch solution:* 1g starch was mixed with small amount of cold water. While stirring 200ml boiling water was added.

   Test for sensitivity of starch solution: 5ml starch solution was mixed in 100 ml water and 0.05ml 0.1N iodine solution was added in to it; deep color was produced and discharged by 0.05ml 0.1N $Na_2S_2O_3$.

4. *Sodium thiosulphate* ($Na_2S_2O_3$) *solution*: 25g of sodium thiosulphate was weighed and dissolved in 1L of distilled water. Solution was boiled, cooled and filtered. Standardized against standard potassium dichromate solution.

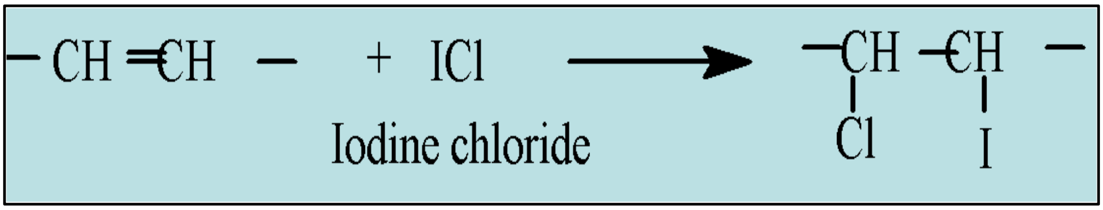
5. *Cyclohexane-acetic acid solvent:* cyclohexane and acetic acid were mixed in equal parts (1+1) (volume/volume).

   Absence of oxidizable matter in cyclohexane-acetic acid solvent: Determined by shaking 10ml solvent with 1ml saturated aqueous potassium dichromate solution and 1ml H_2SO_4. No green color indicates absence of oxidizable matter.

4.3.4.1.6.3 Procedure

1. Sample was filtered to remove any solid impurities and traces of water.
2. Sample was weighed in a conical flask and 15ml cyclohexane-acetic acid solvent added to test sample and swirled to ensure that sample was completely dissolved.
3. 25ml Wij's solution was added into flask containing test sample, stopper flask, and swirl to mix. Immediately timer was set for 1 or 2 h, depending

on IV of sample (IV<150, 1 h; IV≥150, 2 h) and flasks were store in dark at 25 ± 5^{0} for reaction.



4. Flasks were removed from dark; 20ml KI solution was added. 150ml water was added and gradually titrate with 0.1N standard $Na_2S_2O_3$ solution with constant and vigorous shaking.

Excess unreacted ICl

$$ICl + KI \longrightarrow KCl + I_2$$

$$I_2 + 2\ Na_2S_2O_3 \longrightarrow Na_2S_4O_6 + 2\ NaI$$

5. Titration was continued until yellow color almost disappeared; 1-2ml starch indicator solution was added to flasks and continued titrating until blue color disappeared.

4.3.4.1.6.4 *Calculation*

$$IV = \frac{[(B-S) \times N \times 12.69]}{\text{weight of sample}}$$

Where,

B= titration of blank (ml); S=titration of sample (ml); N= Normality of $Na_2S_2O_3$ solution

4.3.4.1.7: Acid value

AOCS Cd 3a-63 method (1974) was used for determination of acid value.

4.3.4.1.7.1 *Principle*

The acid value is the number of milligrams of potassium hydroxide necessary to neutralize the free acids in 1 gram of sample.

4.3.4.1.7.2 Preparation of reagents

1. *Standard potassium hydroxide (KOH) solution:* 0.1N. 6g of KOH was added to 1 litre of water in a 2 liter flask, and then boiled for 10 minutes with stirring. 2g barium hydroxide ($Ba(OH)_2$) added to boiled solution and again boil for 5-10 minutes. Boiled solution was cooled and allowed to stand for overnight, filtered through funnel. KOH solution was standardized by titration with pure potassium acid phthalate using phenolphthalein indicator.

2. *Isopropyl alcohol-toluene solution:* Equal parts by volume of isopropyl alcohol and toluene were mixed and filled in a volumetric flask. Isopropyl alcohol-toluene solution gives a distinct and sharp end point with phenolphthalein in the titration.

3. *1% Phenolphthalein indicator solution:* 1g of phenolphthalein was mixed in 100ml isopropyl alcohol.

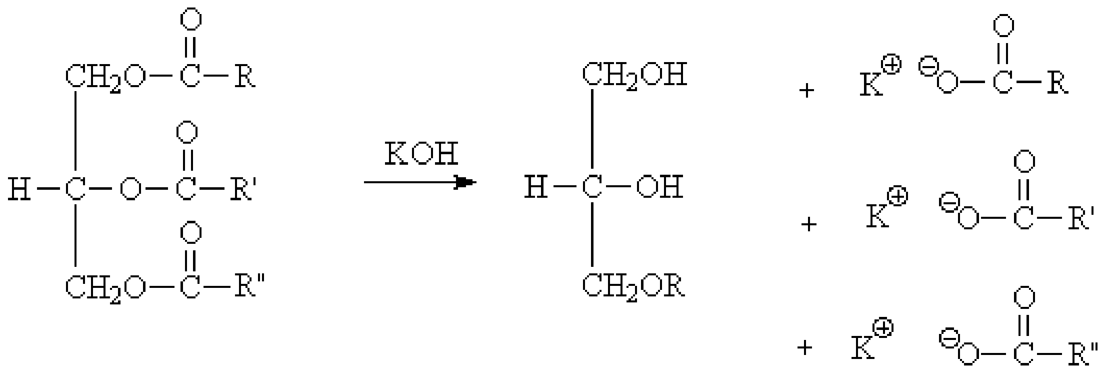
4.3.4.1.7.3 Procedure

1. 10±0.02g of sample was weighed into 250ml conical flask.

2. 2ml phenolphthalein indicator solution was added to 125ml isopropyl alcohol-toluene solution and neutralize with alkali to a faint but permanent pink color.

3. 125ml neutralized solvent mixture was added to sample and dissolved completely before titrating.

4. Sample was whirled while titrating with standard alkali to the first permanent pink color of the same intensity persist for 30 seconds as that of neutralized solvent before the latter, was added to the sample.



TAG + 3 KOH ⟶ glycerol + 3 alkali salt

4.3.4.1.7.4 Calculation

$$\text{Acid value, mg KOH per g of sample} = \frac{\text{ml alkali X N X 56.1}}{\text{Weight of sample}}$$

Where, ml alkali= amount of KOH solution (ml) used

N=normality of KOH solution

4.3.4.2 Physical parameters used to check the quality of CSO and GNO used for frying.

4.3.4.2.1: Refractive Index

AOAC 921.08 method (1995) was used to estimate the refractive index of oils with the help of Abbe refractometer shown in Plate 4.3.4.2.1.

4.3.4.2.1.1 Principle

The refractive index of a medium is the ratio of the speed of light at a definite wavelength in vacuo to its speed in the medium. When light passes from air to fat its direction changes at the interface of two media. The actual change depends on the angle at which the light strikes the fat and order to get a significant value. The refractive index of a given substance varies with the wavelength of the light and with the temperature. The refractive index of fat is related to molecular structure and unsaturation.

4.3.4.2.1.2 Procedure

1. Instrument is based upon observation of position of border line of total reflection in relation to faces of flint glass prism.
   Bring the border line into field of vision of telescope by rotating double prism by means of alidade in following manner: hold sector firmly and move alidade backward or forward until field of vision is divided into light and dark portion. Line dividing these portions is "border line", and as a rule, will not be the sharp line but band of color. Colors are eliminated by rotating screw head of compensator until sharp, colorless line is obtained. Adjust border line so that it falls on point of intersection of cross hairs. Read n substance directly on scale of sector, estimating 4^{th} decimal place.

2. Double prism opened by means of screw head and few drops sample were placed into funnel-shape aperture between prisms. Prisms closed firmly by tightening screw head. And allowed the instrument stand few min before reading, so the temperature of sample and instrument is same. Clean prisms between readings by wiping off oil with cotton pod moistened with solvent (e.g. toluene or petroleum ether), and allowed to dry. Refractive index was noticed from the scale sector of Abbe refractometer (Plate 4.3.4.2.1).

Plate 4.3.4.2.1: Abbe refractometer used for determination of refractive index of oil

4.3.4.2.2: <u>Color</u>

Lovibond Tintometer (Plate 4.3.4.2.2) was used to determine the color of oils by using oils and fats, Manual of methods of analysis of foods, Lab manual 2 (7.0), 2005.

4.3.4.2.2.1 Principle

Determines the color of oils by comparing with Lovibond color racks of known color characteristics. The color is expressed as the sum total of the yellow and red slides used to match the color of the oil in a cell of the specified size in the Lovibond Tintometer .

4.3.4.2.2.2 Procedure

1. Oil sample was filtered through a filter paper to remove any impurities, traces of moisture, clear and free from turbidity.

2. Oil sample color was matched by adjusting yellow (Y) and red (R) racks of the instrument. A glass cell was filled with the sample and placed inside the lightening cabinet. Match the color with sliding red and yellow color racks.

4.3.4.2.2.3 Calculation

Color was reported in terms of Lovibond units as:-

Color reading = (a Y + 5 b R)

Where,

a = sum total of the various yellow slides (Y) used

b = sum total of the various red (R) slides used

Y + 5R is the mode of expressing the color of oils

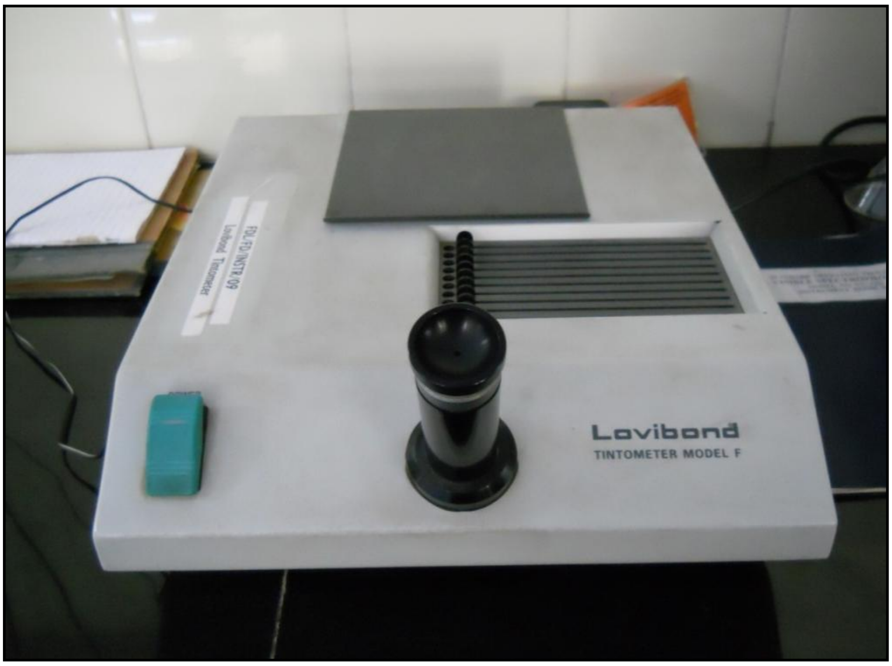


Plate 4.3.4.2.2: Lovibond tintometer for estimation of color of oil used for frying french fries and bhajias

4.3.5 Statistical analysis

Mean and standard deviation of duplicate values obtained by conducting the experiments in replicate were calculated using Microsoft Excel 2007. Analysis of variance (ANOVA) was used to determine significant difference amongst the fried samples at different intervals of frying for their chemical analysis. Student't' test was used to find the significant difference between the two means. Pearson's coefficient was used to calculate correlation between dependent and independent variables. Regression equations in the regression analysis were used to determine if the independent variable (time) had any effect on the chemical indicators.

PHASE IV:

4.4 Case study on prevailing food safety and frying practices in Jan aahar- A government run food outlet at Vadodara railway station.

To study the food safety practices regarding personal hygiene, food hygiene, environmental hygiene, oil storage and frying practices of government run food outlet was selected.

4.4.1 To determine the current knowledge of kitchen staff on food safety practices in terms of personal hygiene, food hygiene, environmental hygiene, nutrition and health.

A pre-tested structured questionnaire was used to assess the knowledge of cooks, waiters, cleaners and supervisors on food hygiene, nutrition and health, and personal hygiene. An observation table was used to assess the prevailing practices of cooking staff on personal, unit and environment hygiene (Appendix 11.5).

4.4.2 To determine the oil procurement and storage practices and frying practices of kitchen staff working at Jan aahar –a Government run food outlet at Vadodara railway station.

Current practices used by cooks for procurement and storage of cooking oil, and frying practices were also reviewed (Appendix 11.5).

4.4.3 Statistical analysis

Per cent mean scores were calculated for knowledge scores of food safety. ANOVA (F-test) was determined to obtain difference amongst the knowledge scores of kitchen staff.

PHASE V:

4.5 Development of Nutrition Health Education (NHE) material in two languages on intake of edible oil, types, and on choices of oils for healthy living and problems during frying of edible oil and its storage.

Nutrition Health Education material was developed with the objective to educate people about recommended intake of edible oils, common types of oils, and to choose correct oil for healthy living. An attempt was made to develop an education material on safe frying practices in two languages (Hindi and English).

4.5.1 To develop IEC material on edible oil, types of oil, and its composition.

"KNOW YOUR FATS AND OILS" education material was developed in two languages with following points:

- Oils and fats
- Types of oils and their sources
- Recommended allowances of fats and oils
- What is the difference between oils and fats
- Do vegetable oils contain cholesterol?
- How to store oil?
- Which fat is heart friendly?
- Recommended combination of oils for optimal health benefits in Indians consuming cereal based diets

- Why fried foods are bad for health?
- What are *trans* fats?

4.5.2 To develop IEC material on frying and problems during frying.

Frying, a cooking method used in various food outlets for preparing variety of foods. Selection of oils and frying practices should be such that they are safe for human consumption.

Hence the Information Education Communication (IEC) material was developed on safety of fried foods, common problems envisaged during frying and calorie content of common fried foods that comprised of following points:

- What is frying?
- What are good frying practices?
- Problems envisaged during frying and their solutions:
    a. Causes of foaming and its solutions
    b. Causes of greasiness and its solutions
    c. Causes of rapid oil breakdown and its solutions
    d. Causes of darkening of oil and its solutions
    e. Causes of smoking and its solutions
- Calories and fat content of some common non-vegetarian fried foods
- Calories and fat content of some common vegetarian fried foods

CHAPTER 3
SCOPE OF INVESTIGATION

The present study was carried out with the broad objective to assess the role of quality and quantity of edible oil intakes, frequency of fried food intake by Gujarati housewives and its association with their morbidity profile, assess the sensory qualities of french fries and bhajias fried in cottonseed and groundnut oil at different intervals, determine the intermittent frying stability of cottonseed and groundnut oil, and also to assess the food safety and frying practices prevailing at the Government run food outlet at Vadodara railway station.

The specific objectives of the present study included:

PHASE I

- To determine the frequency of consumption pattern of Gujarati households for deep fried foods, shallow fried foods and deep fried sweets prepared at home and purchased from market.
- To determine the morbidity profile of Gujarati housewives with respect to BMI, diabetes, hypertension and gastrointestinal problems and further determine the association between health status and fried food consumption.
- To collect information on type of oil consumption, frying practices, oil storage practices, knowledge on oil blends and *trans* fats of Gujarati house wives.

PHASE II

- To assess the sensory quality of french fries and bhajias fried in cottonseed and groundnut oil at intermittent durations.

PHASE III

- To determine the effect of intermittent frying stability of cottonseed oil and groundnut oil used for frying french fries and bhajias in terms of its breakdown products (peroxide value, p-anisidine value, acid value, iodine value, refractive index and color).
- Determination of fatty acid profile and total polar components at different frying intervals.

PHASE IV

- To determine the current knowledge of Jan aahar kitchen staff on food safety practices in terms of personal hygiene, food hygiene, environmental hygiene, nutrition and health
- To determine the oil procurement, storage and frying practices of cooks working at Jan aahar.

PHASE V

- To develop IEC material on intake of edible oil, types, and on choices of oils for healthy living.
- To develop IEC material on frying and problems during frying.

CHAPTER 2

REVIEW OF LITERATURE

The human diet contains a wide range of different foods. Solid foods contain protein, carbohydrate and **fat (lipid)** as three macronutrients, along with a large number of important micronutrients (Gunstone FD, 2005). Dietary fat encompasses all the sources of lipids in foods, including those in plant and animal cellular membranes, as well as the readily recognized fats and oils. National Council for Applied Economics Research (NCAER, 2012) reported use of vegetable oils (excluding *vanaspati*) for cooking has grown from 7 kg in the 1990s to 13.5 kg in recent years in India. Fried food is a convenience food in most countries. Unfortunately, these are high in fat and contribute to fat-related diseases in societies with a high fat consumption (Mehta U and Swinburn B, 2001).

The present work has been undertaken to study the frequency of fried food intake by Gujarati housewives and its association with their morbidity profile, assess the sensory qualities of french fries and bhajias fried in cottonseed and groundnut oil at different intervals, determine the intermittent frying stability of cottonseed and groundnut oil.

This chapter focuses on the available literature for the various objectives of the study and divided into the following heads:

2.1 Global consumption and recommended intakes of edible oil

2.2 Edible oil consumption in India

2.3 Production of edible oil

2.4 Nutrition transition

2.5 Chronic diseases related to fats and oil consumption

  2.5.1 Per cent energy from oils in Indian diets

  2.5.2 Fried food consumption in India and its association with metabolic disorders

2.6 PFA/FSSAI standards for edible oils

2.7 History of fried foods

2.1 Global consumption and recommended intakes of edible oil

The increase in the quantity and quality of the fats consumed in the diet is an important feature of nutrition transition reflected in the national diets of countries. There are large variations across the regions of the world in the amount of total fats (i.e. fats in foods, plus added fats and oils) available for human consumption. The lowest quantities consumed are recorded in Africa, while the highest consumption occurs in parts of North America and Europe. The important point is that there has been a remarkable increase in the intake of dietary fats over the past three decades (Table 2.1.1) and that this increase has taken place practically everywhere except in Africa, where consumption levels have stagnated. The per capita supply of fat from animal foods has increased, respectively, by 14 g and 4 g per capita in developing and industrialized countries, while there has been a decrease of 9 g per capita in transition countries (Kennedy G, 2005).

Table 2.1.1: Changed trends in the dietary supply of fat from 1967-99

Region	Supply of fat (g/capita/day)				
	1967 – 1969	1977 – 1979	1987 - 1989	1997 – 1999	Change between 1967 - 1969 and 1997 - 1999
World	53	57	67	73	20
North Africa	44	58	65	64	20
Sub-Saharan Africa[a]	41	43	41	45	4
North America	117	125	138	143	26
Latin America and the Caribbean	54	65	73	79	25
China	24	27	48	79	55
East and South-East Asia	28	32	44	52	24
South Asia	29	32	39	45	16
European Community	117	128	143	148	31
Eastern Europe	90	111	116	104	14
Near East	51	62	73	70	19
Oceania	102	102	113	113	11

Source: Kennedy G, 2005

FAO (2011) reported annual average increase in vegetable oil consumption is 2.2%. This growth concentration is mainly projected to developing countries due to their solid economic performance and emerging economies, continued population growth and urbanization especially in Asia, notably India, China. However, in developed countries increase is weaker due to slow economic recovery, non-food uses i.e. for biofuel production (Thoenes P, 2011).

As reported by USDA (2012), Figure 2.1 depicts the global edible oil consumption based on world population growth and estimated growth in edible oil consumption with increase in world population. According to USDA 2012, edible oil consumption is projected to grow at slower rates in proportion with the future lower population growth, total edible oil consumption will increase from 145mn tones today to 660mn tones by 2050, and the % of palm oil of total consumption will increase from 36% to 58%.

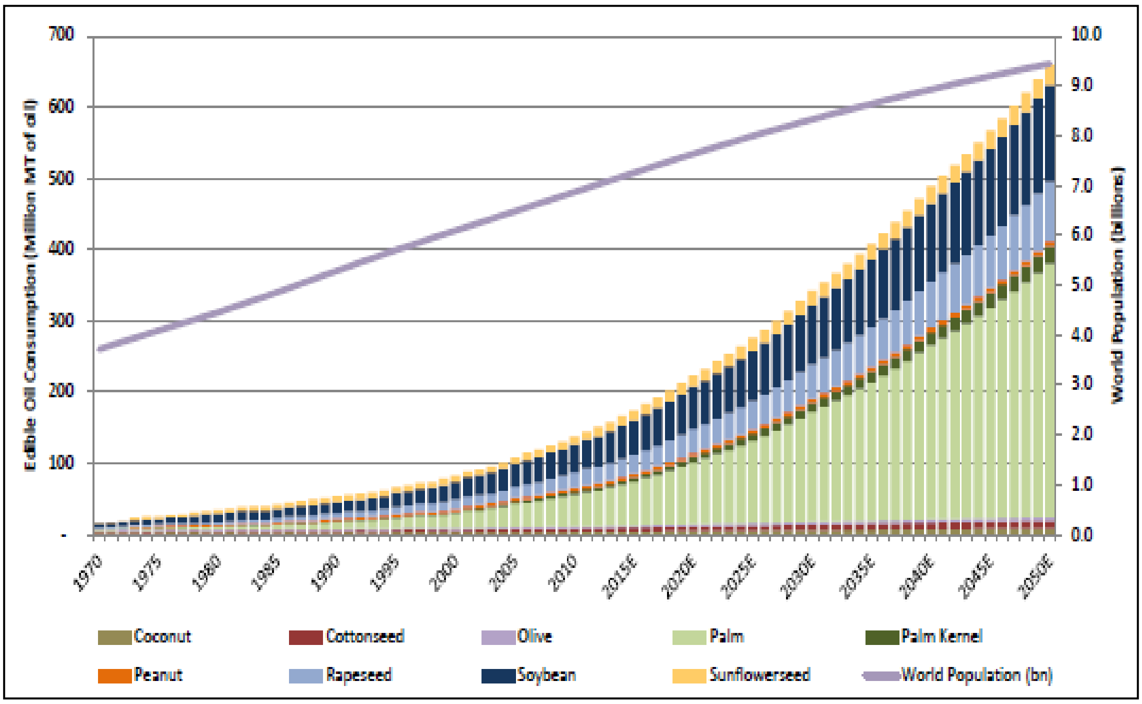


Figure 2.1: Estimated global edible oil consumption based on world population growth

Table 2.1.2: Average yearly oil consumption growth assumptions

	1971-1980	1981-1990	1991-2000	2001-2010	2011-2020E	2021E-2030E	2031E-2040E	2041E-2050E
Coconut	3.7%	1.6%	0.6%	3.2%	2.8%	2.3%	1.9%	1.5%
Cottonseed	0.2%	1.5%	1.9%	3.1%	2.7%	2.2%	1.8%	1.4%
Olive	2.0%	0.5%	4.0%	2.0%	1.7%	1.4%	1.1%	0.9%
Palm	10.7%	9.5%	7.1%	8.2%	7.2%	5.9%	4.8%	3.8%
Palm Kernel	3.8%	8.9%	8.3%	6.4%	5.7%	4.7%	3.7%	3.0%
Peanut	2.6%	2.8%	2.5%	1.5%	1.3%	1.1%	0.9%	0.7%
Rapeseed	6.4%	9.5%	6.3%	5.2%	4.6%	3.8%	3.0%	2.4%
Soybean	8.2%	2.6%	4.5%	4.8%	4.2%	3.5%	2.8%	2.2%
Sunflowerseed	5.2%	5.7%	1.1%	3.0%	2.7%	2.2%	1.8%	1.4%
Palm as % Total Consumption	**12.5%**	**17.9%**	**24.7%**	**33.2%**	**39.0%**	**45.8%**	**51.4%**	**55.9%**
Average Population Growth (Yearly)	*1.8%*	*1.7%*	*1.4%*	*1.2%*	*1.1%*	*0.9%*	*0.7%*	*0.6%*
Change in Population Growth					*-11.9%*	*-17.9%*	*-19.6%*	*-19.4%*

Source: USDA, 2012; U.S. Census Bureau, International Data Base, Internal estimates

Recommended guidelines for dietary fat intake

The World Health Organization/Food and Agriculture Organization (WHO/FAO, 2003) has recommended national dietary guidelines on fat intakes.

❖ ***World Health Organization (WHO) Guidelines***

The WHO/FAO 2003 issued the following recommendations with respect to fat intake

- Saturated fat <10% of total energy, or <7% in high risk individuals
- <1% of energy from *trans* fatty acids
- 6–10% total energy from PUFA
- Maintain a balance of n-6 PUFA and n-3 PUFAs i.e. 5–8% and 1–2% of daily energy intake respectively, which corresponds to an n-6:n-3 PUFA range of 2.5:1–8:1.
- The WHO recommends PUFA/SAFA ratio of 0.8 to 1.0 and linoleic acid (omega 6) alpha linolenic acid (omega 3) ration of 5-10 in the diet.
- Total fat, no specific recommendation, but suggests up to 35% in highly active group, with diets rich in fruit, vegetables, legumes, and wholegrain cereal. Otherwise considerable lower fat intakes are recommended.
- Eat fish once or twice a week.

❖ ***American Heart Association***

The American Heart Association recommends total fat intake to less than 25-35 per cent of total calories. A saturated fatty acid intake of not more than 10 per cent of total calories, a monounsaturated fatty acid intake in the range of 10-15 per cent and polyunsaturated fats up to 10 percent of total calories. Cholesterol intake should be less than 300mg/d (Krauss RM et al, 1996).

❖ *UK Guidelines*

In the UK, the following recommendations for dietary fat compositions, based on reducing CHD incidence, have been set (Hunty A, 1995; Food Standards Agency, 2004).

- Total fat <35% food energy (<33% including alcohol)
- Saturated fat <11% food energy (<10% including alcohol)
- *Trans* fatty acids <2% food energy
- Monounsaturated fatty acids- 13%
- Polyunsaturated fatty acids (including n-3 PUFA and n-6 PUFA) – 6.5%
- Long chain n-3 PUFA (LC n-3 PUFA, EPA+DHA) - 0.45 g/d (derived from 2 portions of fish per week, one oily)

Several countries have recommend allowances not only for the absolute amount of PUFAs, but also the balanced intake of n-6 and n-3 PUFA. These recommendations are summarized by Sugano M and Hirahara F (2000) shown in Table 2.1.3.

Table 2.1.3: Recommended dietary allowances of fats in the world

Country	Total energy intake from fats	Total PUFA	Omega 6 (LA)	Omega 3 (ALA)	Omega 6/Omega 3
		% of energy			
WHO (1990)	15-30	3-7, ≤10	-	-	5-10
FAO (1994)	15-35	-	4-10	-	5-10
USA (1989)	<30	7	1-2	-	4-10
Japan (1995)	20-25	7-8	-	-	4
Canada (1990)	30#	≥3.5	≥3	≥0.5	4-10

Note: # Intake of saturated fat should be ≤10% of energy

PUFA, polyunsturated fatty acid; LA, linoleic acid; ALA, a-linolenic acid

2.2 Edible oil consumption in India

Edible oils constitute an important component of food expenditure in Indian households. Historically, India has been a major importer of edible oils with almost 30-40% of its requirements being imported till 1980s (ICRA, 2011).

India engrossed over 15 percent of global vegetable oil imports in 2002/03, making it the world's leading importer, ahead of the European Union and China. Imports represent about 55 percent of India's edible oil consumption and about half the value of its total agricultural imports (Figure 2.2.1) (Dohlman E, Persaud S and Landes R, 2003).

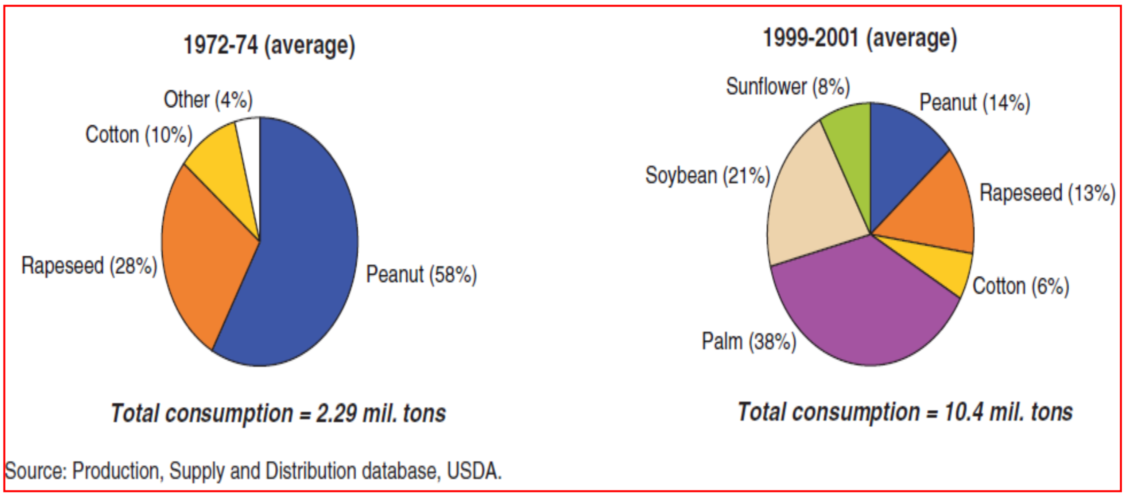


Figure 2.2.1: Dramatic rise India's average consumption of edible oil

USDA estimates, India is the third largest consumer of edible oils (after China and the EU-27 countries); and account for 11% of global edible oil demand and 16% of global imports in 2010/11. India's annual per capita consumption has shown a steadily increasing trend from 4 kg in the 1970s to 10.2 kg in the late 1990s to current levels of ~13.5 - 14 kg (Figure 2.2.2) (ICRA, 2011).

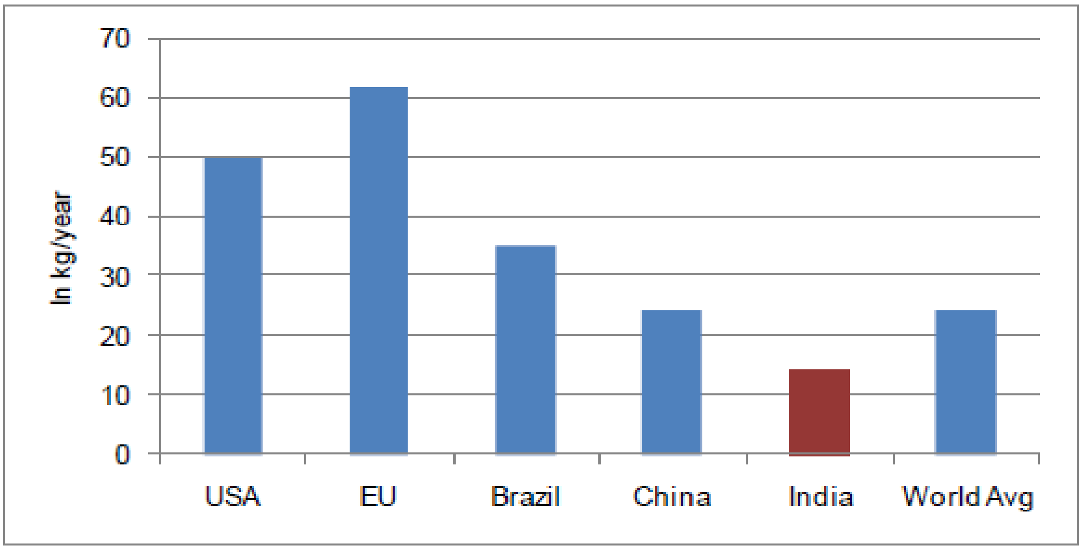


Figure 2.2.2: Per capita consumption of edible oils (2009-10)

However, it still ranks well below the world average of around 24 kg (per capita figures including consumption of bio-energy).

Indian edible oil consumption pattern is the variation in preferences across regions, driven by taste and availability. For instance, soybean oil is mainly used in northern and central regions of India due to the local availability of soybeans. Mustard oil is largely consumed in north-eastern, northern and eastern regions of India, as its pungency is a desired and inherent part of the local cuisine. In terms of volume, palm, soybean and mustard/rapeseed oil are the three major edible oils consumed in India and together account for 75% of the total edible oil demand (Figure 2.2.3) (ICRA, 2011).

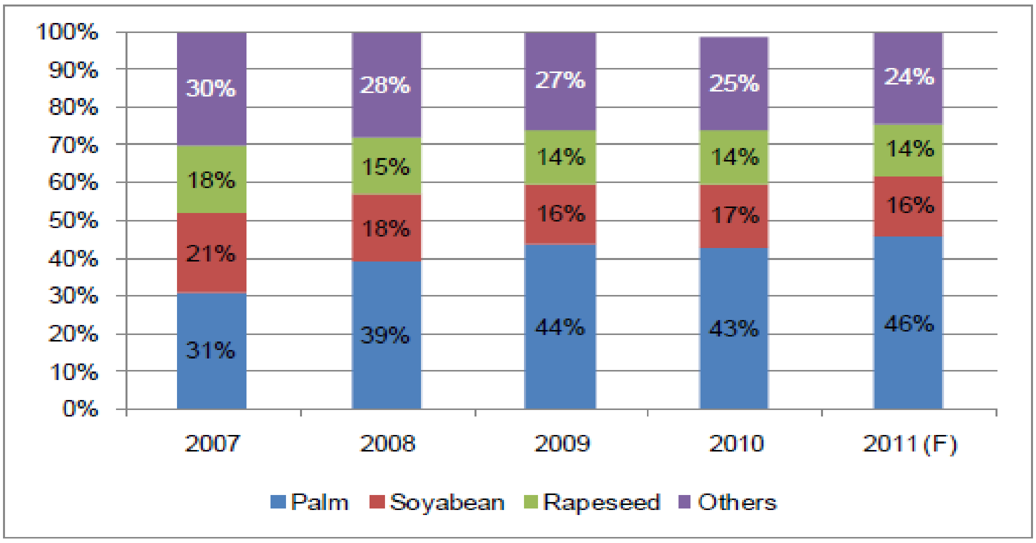


Figure 2.2.3: Domestic consumption trend

USDA predicted the edible oil consumption in 2010/11 increase by 5 percent to around 15.7 million tons due to increasing population and good supply conditions. The per capita edible oil consumption in India is increasing and is estimated at 13.4 kg for 2009/10, which however, is far below the world average per capita consumption of 20.98 kg (Figure 2.2.4). The vegetable oil deficit in 2010/11 was around 8.7 million tons and met through imports (USDA, 2010).

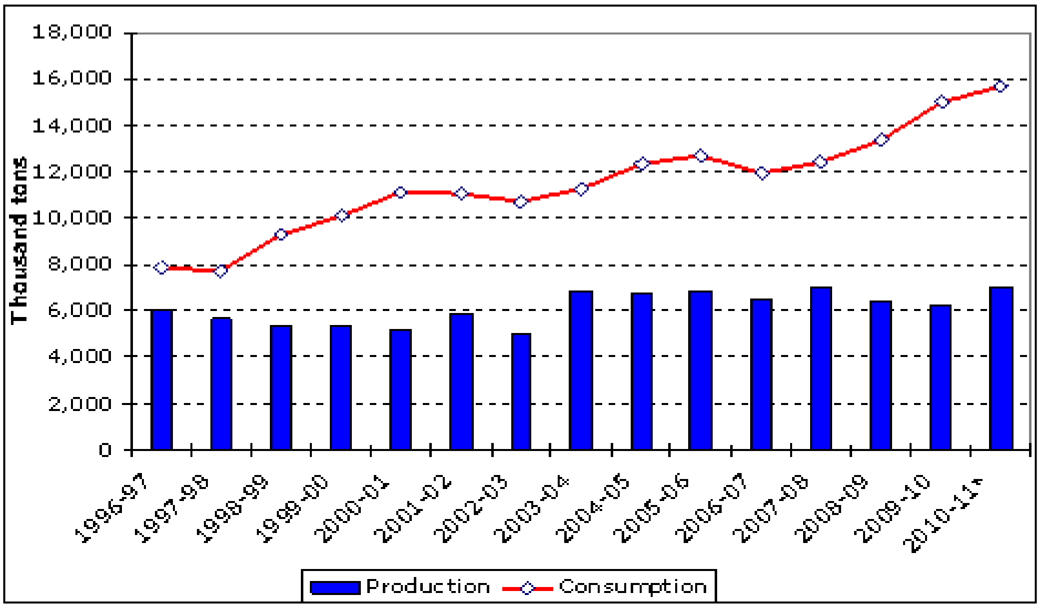


Figure 2.2.4: Edible oil production and consumption (1997 through 2011)

The pattern of edible oil consumption in India has traditionally been region-specific. Coconut, peanut and sunflower oil are widely consumed in south India, **peanut and cottonseed oils are used in Gujarat**, rapeseed oil in north east India, and soybean oil in central India (USDA, 2010).

2.3 Global production of edible oil

Worldwide 12 oil crops constitute over 95% of total vegetable oil production. From 1979 to 1999, oil crops have been one of the most dynamic agricultural sectors growing at a rate of 4.1% per year (Minihane AM and Harland JI, 2007). Hawkes C (2006) reported, FAOSTAT data world oil crop production increased by over 60% between 1990 and 2003 as shown in Table 2.3.1.

Table 2.3.1: World oil crops primary production (Mt)

1980	1990	1995	2000	2003	2004
49,298,300	75,410,698	91,875,399	110,043,440	123,168,460	132,726,738

Source: Hawkes C, 2006

Between 1994 and 2004, edible oil production in China increased nearly two-fold, soybean oil production in Brazil by one-half and Argentina by twofold, and palm oil production in Malaysia increased by two-thirds (Beckman C, 2005). Similar trends are seen for consumption. During this time frame, vegetable oil consumption in the United States and Western Europe increased by just one-quarter, whereas it doubled in China and increased by **one-half in India**. Overall, between 1982/84 and 2000/02, vegetable oils contributed more than any other food group to the increase of calorie availability worldwide (70 kcal/capita/day). Vegetable oils can thus clearly be implicated in rising dietary fat intakes worldwide (Drewnowski A, Popkin BM, 1997).

Total production of oil crops is predicted to increase from 104 to 217 million tons between 1999 and 2030 (Table 2.3.2) (Kennedy G, 2005).

Table 2.3.2: FAO predicted values of world production of major oil crops

	Production of oil crops in oil equivalent (million tonnes)			
Source	1964/66	1984/86	1997/99	2030 (predicted)
Soybeans	5.8	17.2	27.7	58
Palm oil	2.1	8.7	21.6	49
Rapeseed	1.7	7.1	14.5	32
Sunflower	3.4	7.5	10.3	21
Groundnuts	4.8	6.1	9.4	20
Coconuts	3.1	4.3	6.0	12
Cottonseed	3.4	5.0	5.3	9
Sesame seeds	0.7	1.0	1.2	3
Other oil crops	3.7	4.8	7.6	13
Total	29.0	62.0	104.0	217

Source: Kennedy G, 2005

The prime use of the commercial oils and fats produced by the agricultural industry is as food for humans. This represents 80 per cent of the total (122.5 million tons in 2002/03) i.e. around 98 million tones, equivalent 19.7 kg/person/year or 54 g/person/day. These figures are obtained by dividing total annual production by world population. Average values may vary between countries for example: total disappearance per person in 2002/2003 (including that used as animal feed and in the oleo chemical industry) is 50.9 kg for United States, 50.5 kg for EU-15, 16.4 kg for China, and 11.5 kg for India. The fats we consume are of animal and vegetable origin (Gunstone FD, 2005).

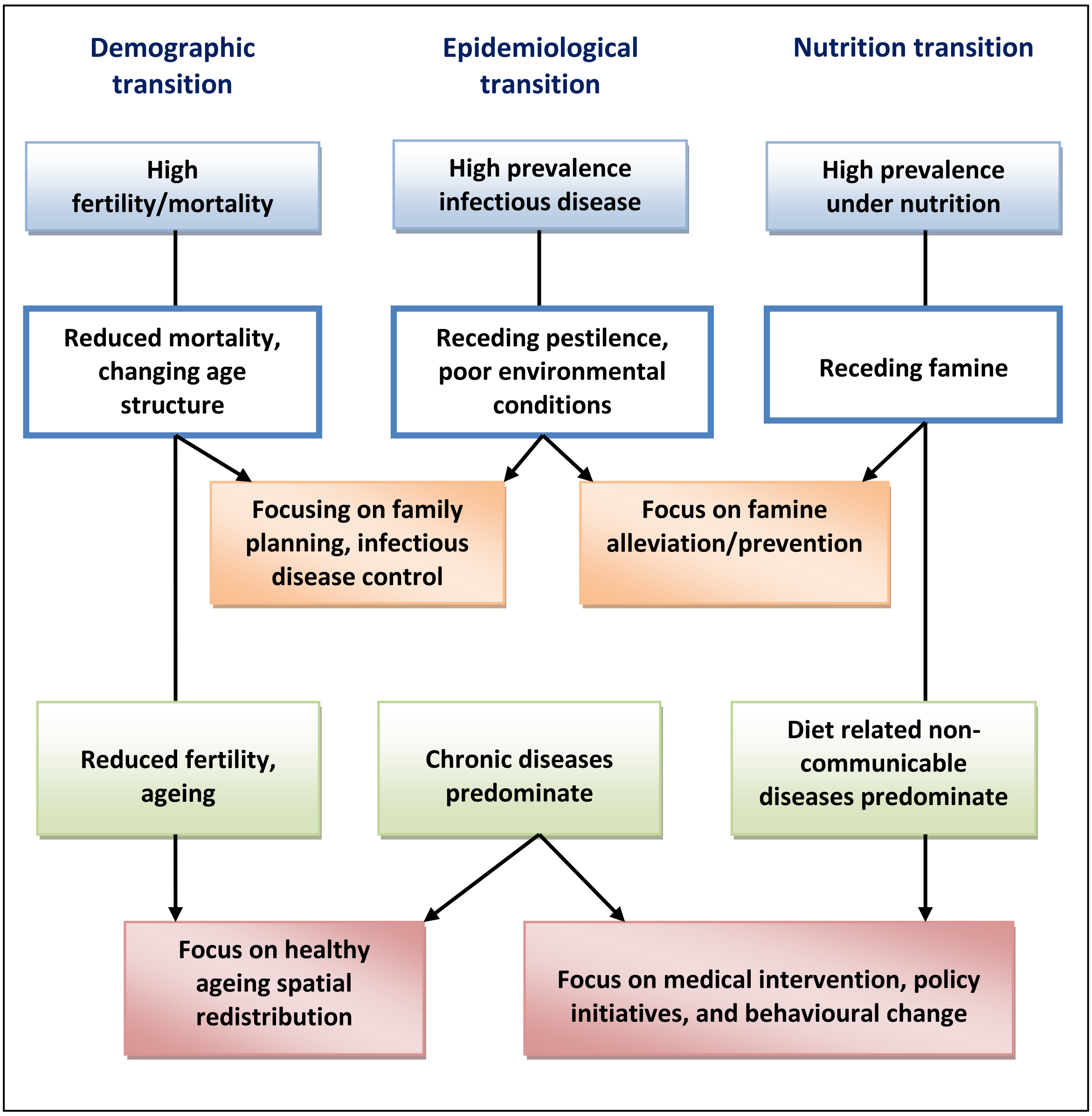
Review report by Dohlman E, Persaud S, and Landes R (2003) stated, India itself is the world's fifth largest producer of soybean oil. India is the world's leading importer of edible oils and is likely to remain an important source of global import demand for the foreseeable future. A large population and steady economic growth are important contributors to India's increasing edible oil consumption and imports.

2.4 Nutrition transition

Worldwide 3 types of transitions have been occurring over the past 3 decades (Figure 2.4.1): 1) the demographic transition, 2) the epidemiological transition, and 3) **the nutrition transition** (Kennedy ET, 2005).

The **demographic transition** has been caused by declining fertility rates and increased life expectancy. This has resulted in changes in the age structure of both developing and industrialized countries. India is in the phase of a rapid demographic transition. Life expectancy is increasing while birth rates are on the decline. The aged population (over 60 years) will constitute 13.3% of the 1333 million total populations by 2026 (Shetty PS, 2002).

The **epidemiological transition** is linked to the demographic transition. Disease patterns worldwide are shifting from communicable to non-communicable diseases (NCD). The burden of chronic disease is increasing rapidly, including in some of the poorest countries of the world. WHO estimates that by 2020, chronic diseases will account for ~75% of all deaths worldwide (WHO, 2003). Evidence of epidemiological transition is obvious in India with NCDs contributing increasingly to premature deaths in adults, particularly in urban areas.



Source: Kennedy ET, 2005

Figure 2.4.1: Stages of health, nutritional and demographic change

Rural-urban differences in non insulin dependent diabetes mellitus (NIDDM) and coronary heart disease (CHD) within a region or state in India show variants in disease risk depicted in Table 2.4.1, suggesting that internal migration, urbanization and exposure to changing diet and lifestyles increase the risk of chronic disease (Shetty PS, 2000).

Table 2.4.1: Urban-rural differences in chronic disease risk in developing societies

	NIDDM prevalence, Tamil Nadu (%)	CHD prevalence, Delhi (%)	CHD prevalence, Moradabad (%)	Cancer incidence, Delhi vs. Barshi, 100,000
Urban	8.2	9.7	9.0	118.8
Rural	2.4	2.7	3.3	57.6

Source: Shetty PS, 2000

The concept of the **nutrition transition** focuses on large shifts in diet and activity patterns, especially their structure and overall consumption (Popkin BM, 2006). The nutrition transition involves populations shifting from a traditional grain-based diet to one with increased variety including more fat and sugars. The change in dietary patterns is related to urbanization. As populations shift from rural to urban living, dietary patterns diversify to include more energy dense foods. The shift in diet occurs at the same time that levels of physical activity are decreasing (Kennedy ET, 2005).

These poor quality diets are associated with rising rates of overweight, obesity and diet-related chronic diseases, like heart disease, diabetes and some cancers. More people now die of heart disease in developing countries than in developed, and the problem is becoming more serious among the poor (WHO, 2005). Low quality diets are also associated with under nutrition in the form of micronutrient deficiency, which, in turn, lowers immunity to infectious diseases. Poor diet quality is thus associated with a dual burden of malnutrition and disease.

Shetty PS in 2002 reported that in India higher-income groups consumed a diet with 32% of the energy from fat while the lower income groups consumed only 17% energy from fat.

Dietary transformation can be described as "increased consumption of brand-name processed and store-bought food, an increased number of meals eaten outside the home and consumer behaviors driven by the appeal of new foods available". The process of diet transformation in India can be seen as in two separate stages (Pingali P and Khwaja Y, 2004; Hawkes C, 2006):

- **Income-induced diet diversification**

At the start of the process of faster economic growth, diets diversify but maintain predominantly traditional features.

- **Diet globalization**

As globalization begins to exert its influence, we see the adoption of markedly different diets that no longer conform to the traditional local habits.

The links between globalization and diet suggested by analysts have the following mechanisms (Figure 2.4.2) are central to the globalization/diet nexus (Beaglehole R Yach D, 2003; Evans et al, 2001; Hawkes C, 2005; Lang T, 1999).

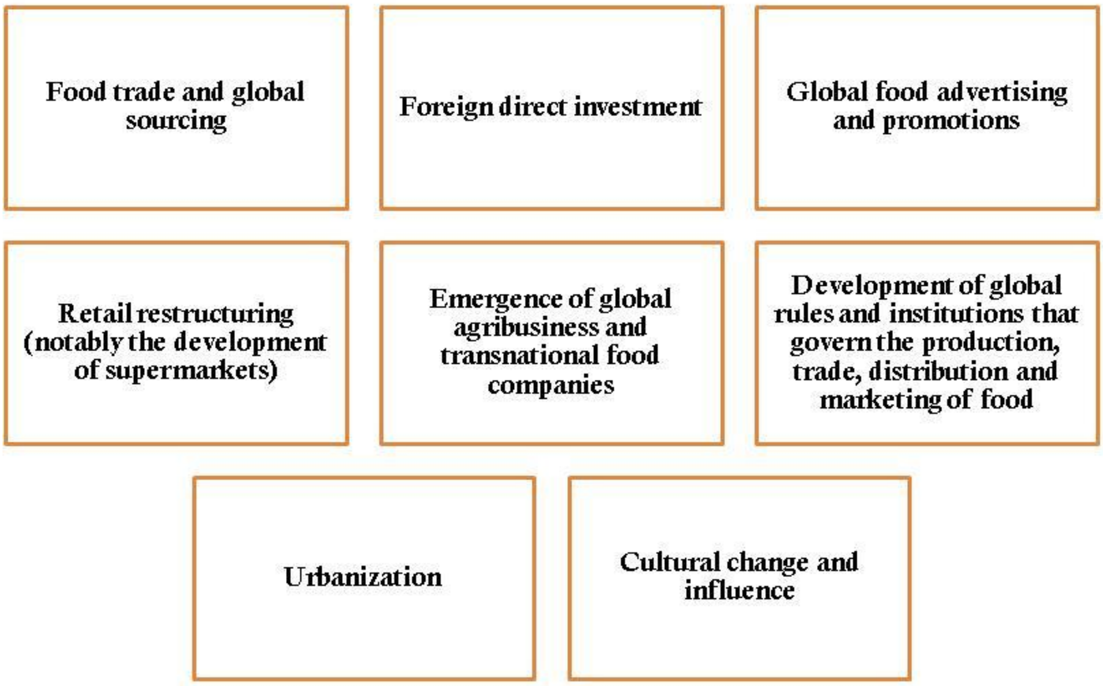
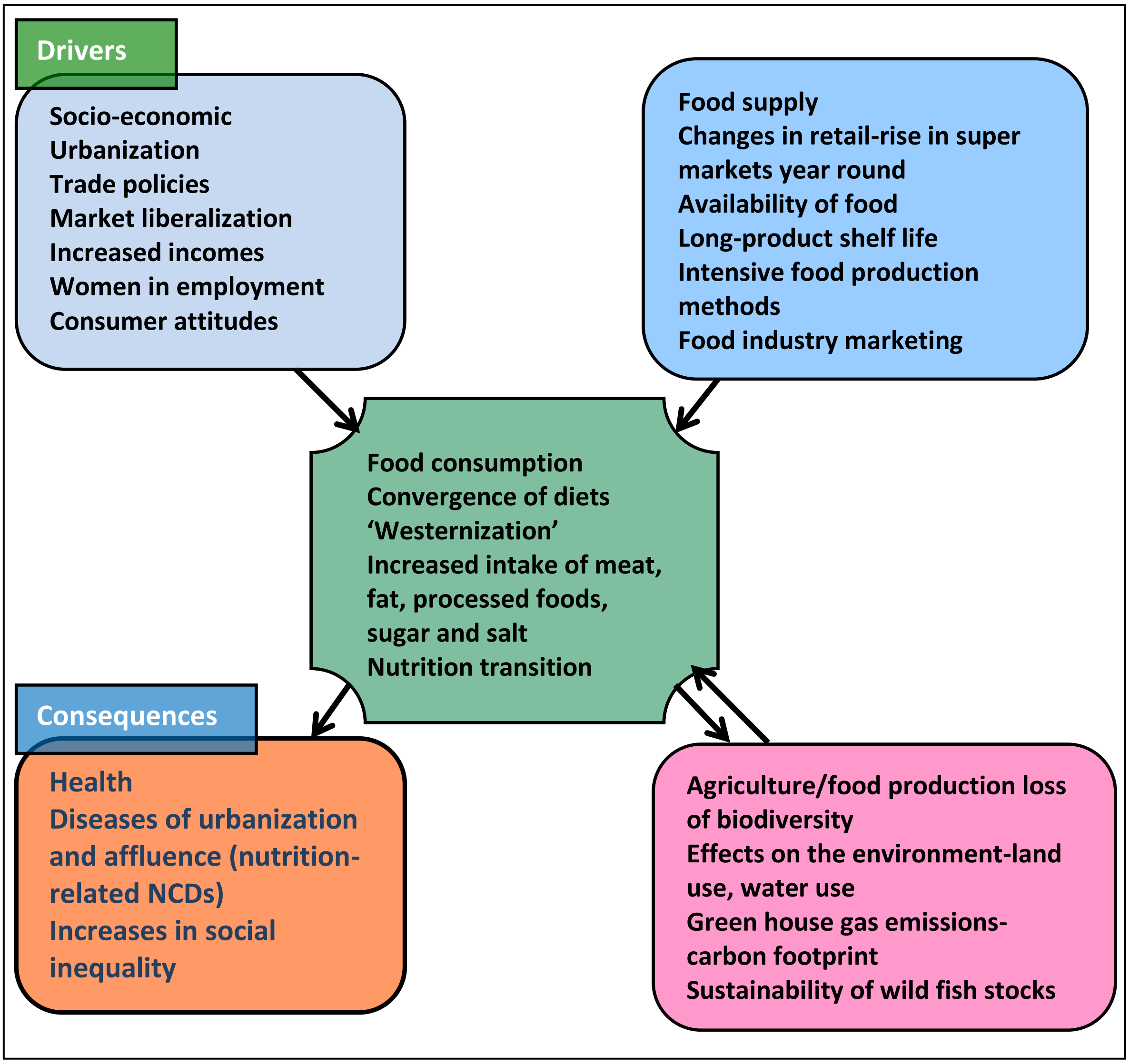


Figure 2.4.2: Mechanisms to the globalization and diet nexus

A difficulty in arresting the effects of the nutrition transition is due in part to the paradox that while the diet associated with the nutrition transition (high fat, sugar and salt) is unhealthy, it is also more diverse and pleasurable (fat and sugar are two of the most pleasurable elements of the diet in terms of taste preferences). This then is part of the challenge: to provide more varied and tasteful diets while ensuring that these diets and a healthy activity level reduce the incidence in obesity, adult-onset diabetes and cancer related to nutrition and exercise. The relationship between recent food consumption patterns, some of their drivers and possible consequences are outlined in Figure 2.4.3 (Kearney J, 2010).



Source: Kearney J, 2010

Figure 2.4.3: The drivers and consequences of food consumption changes with economic development

2.5 Chronic diseases related to fats and oil consumption

The food we eat plays a critical role in our overall health. The amount and composition of fat in the diet is an important determinant of the pathobiology of many of illness conditions. Dietary fat related health problems can be categorized in three ways:

a) Total fat intake

A high dietary fat consumption is a major contributor to obesity for a variety of physiological reasons (Miller WC et al, 1990; Swinburn B and Ravussin E, 1993). There are multiple health consequences from obesity, the most important being type II diabetes.

Colditz GA et al (1995) reported that excess body weight is by far the most potent modifiable factor for type II diabetes.

The risk of certain cancers may be increased by total fat intake. Epidemiological studies have shown that a high total fat intake is linked to increased rates of breast, colon, and prostate cancer (Armstrong B and Doll R, 1975; Mc Keown-Eyssen CE and Bright- See E, 1984).

The American Cancer Society (1996) has suggested a 50% reduction in fat intake (from 40 to 20% of energy intake) would significantly reduce the incidence of cancer of the colon, breast, and other cancers.

Total fat intake is much smaller contributor to coronary heart disease (CHD) than the type of fat (Kennel WB et al, 1986; Grundy SM, 1988). Total fat intake may influence some of the major risk factors for CHD particularly through its impact on obesity and type II diabetes.

A study on high fat meal association with atherosclerosis revealed that a high-fat meal impair vasoactivity and transiently impair endothelial function (Vogel RA, Corretti MC and Plotnick GD, 1997).

b) Type of fat intake

Dietary fat composition is arguably the most important dietary factor contributing to the pathology of CVD and diabetes. Links to cardiovascular disease (CVD), degenerative and inflammatory arthritis, cancer and osteoporosis, and the recognition of fats or their derivatives as biological effectors of human pathologies have fueled efforts to characterize the behavior of lipids in vivo. Initially, the association of cholesterol and saturated dietary fat with increased risk of CVD spurred dietary recommendations to reduce the intake of animal fat and to increase the intake of plant oils. However, mounting evidence is now showing that with increased dietary intake of plant oils, such as corn, safflower, and soybean (especially the partially hydrogenated form), which are high in LA, the dietary ratio of n-6/n-3 fatty acids has increased significantly during the past years (Minihane AM and Harland JI, 2007). The high intake of n-6 with an inadequate amount of n-3 fatty acids in the diet could contribute to the development of some cancers and other chronic diseases.

Numerous dietary factors have been implicated in the pathogenesis of hypertension, and measures to control blood pressure have included reducing the intakes of salt and alcohol, as well as fat intake in obese persons (Nurminen ML, Korpela R, Vapaatalo H, 1998).

Strong association was found between hypertension and obesity. The presence of excess polar compounds in the cooking oil and the use of sunflower oil were related to the risk of hypertension, whereas the concentration of monounsaturated fatty acids in the serum phospholipids was negatively related to this risk (Soriguer F et al, 2003).

Elaidic acid, one of the principal *trans* isomers produced during industrial hydrogenation of edible oils, adversely affects plasma lipoproteins (Sundram K, 1997), including higher intake of trans fat is strongly associated with coronary heart disease (Oh K et al, 2004).

c) Degraded fat and potential health effects

i) Direct toxicity

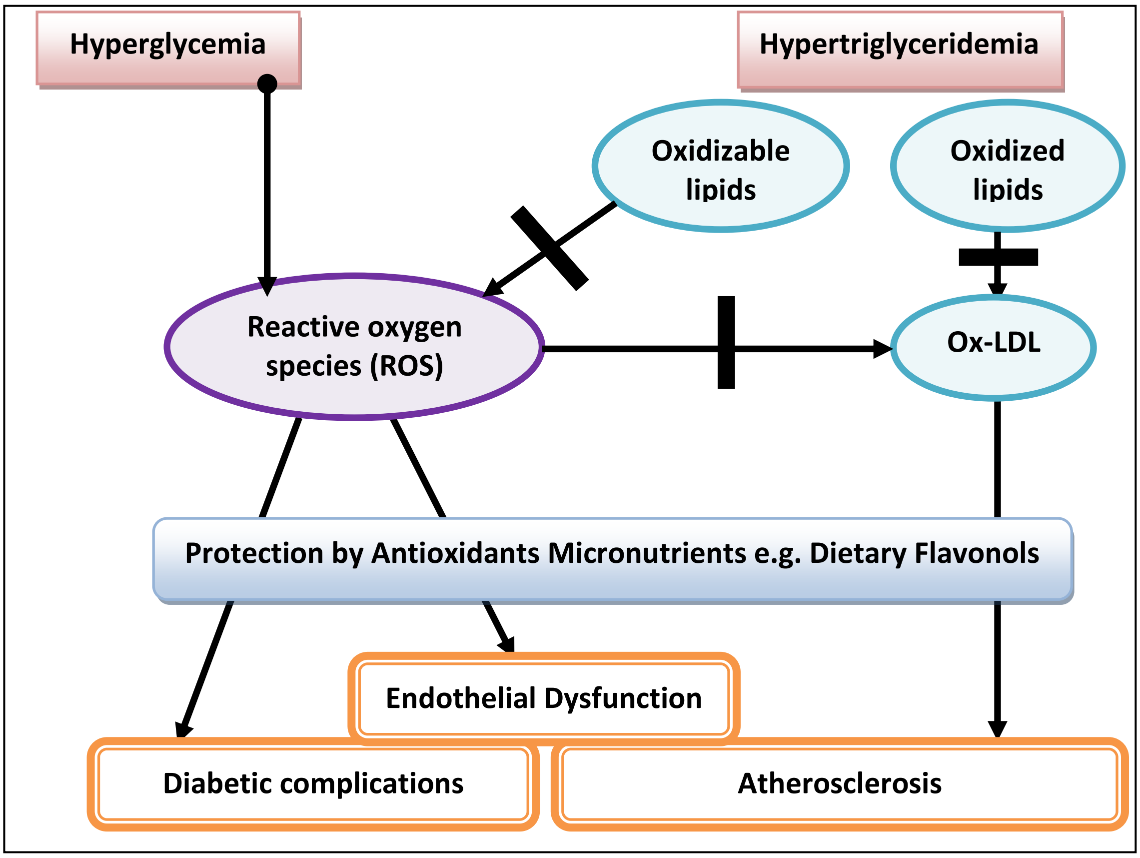
A number of reactions occur in the frying fat when foods are fried, causing oxidative and hydrolytic degradation and polymerization of the fat.

In vitro techniques have shown that hydroperoxides do not inhibit lipase activity, though the reaction of lipid peroxides with enzyme protein may reduce its biological activity (Miyashita K, Tagaki T and Frankel EN, 1990).

Hydrolysis of oils used in frying revealed that significantly reduced level of total hydrolytic products are produced from most degraded oils (Nus M, Sanchez-Muniz J and Sanchez-Montero JM, 2006).

ii) Oxidized fat and heart disease

Postprandial oxidative stress is characterized by an increased susceptibility of the organism toward oxidative damage after consumption of a meal rich in lipids and/or carbohydrates (Figure 2.5.1) (Bowen PE and Borthakur G, 2004).



Source: Tsai WC et al, 2004

Figure 2.5.1: Postprandial oxidative stress and its relation to atherosclerosis and diabetes

Studies have reported that cooking fats that have been repeatedly heated and cooled increase the dietary atherogenic, the forerunner to cardio vascular disease; pathogenic conditions of the digestive tract; mutagenic and genotoxicity, properties that often signal carcinogenesis; and teratogenicity, the property of chemicals that leads to the development of birth defects on those who consume them. Although opinions about the direct effect of ingesting individual fat breakdown products vary, the consensus seems to be that thermal oxidation products formed in fats used over extended time period are potentially harmful (Fenton D and Eyres L, 1984; Grootveld M et al, 2001).

Structural changes in fats and oils increased at high temperature, results in producing thermal oxidation products. Due to repeated frying, thermally oxidized oils contain complex mixtures of products such as oxidized TG (Triglyceride) monomers, TG dimres, and TG polymers. These products are associated for change in physicochemical properties of fats. Consequently, the oil/water interface may vary and the lipolytic activity of the lipase may be altered (Nus M, Sanchez-Muniz J and Sanchez-Montero JM, 2006).

In vivo studies reported as the presence of dimers and polymers increased in oxidized oils, declines its digestibility and part of polymers are eliminated in the feces (Potteau B et al, 1977). True digestibility of non-oxidized TG was greater than that of oligomers. As the number of uses increased polar compounds increased in palmolein thus reducing the digestibility ratio (Gonzalez-Munoz MJ, Bastida S and Sanchez-Muniz FJ, 1998).

Study by Sheehy PJA, Morrissey PA and Flynn A (1994) on chicks fed on thermally–oxidized sunflower oil reported that chronic ingestion of oxidized lipids may contain free-radical-scavenging activity and deplete α-tocopherol in the gastrointestinal tract, plasma and other tissues.

Lipid oxidation products have attracted much attention because of the wide variety of degenerative processes and diseases associated, including mutagenesis, cell transformation and cancer; atherosclerosis, heart attacks and chronic inflammatory diseases (Figure 2.5.2) (Saguy IS and Dana D, 2002; Dobarganes MC and Marquez-Ruiz G, 2003; Dobarganes MC and Marquez-Ruiz G, 2006; Kanner J, 2007).

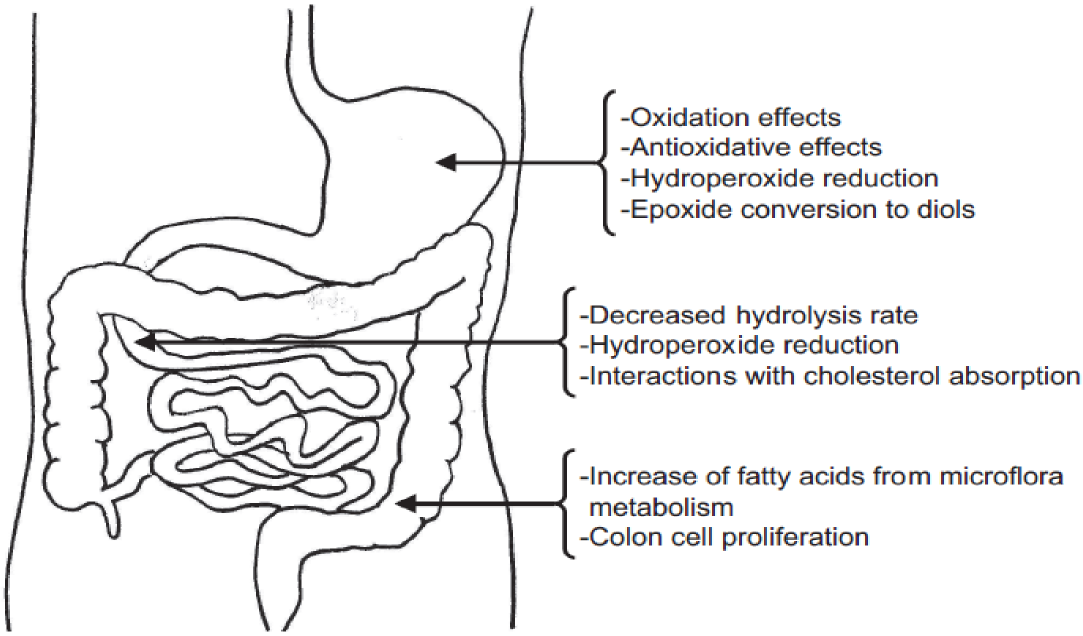


Figure 2.5.2: Main changes and effects reported for dietary oxidized lipids in the gastrointestinal tract

Marquez-Ruiz G, Gracia-Martinez MC and Holgado F (2008) stated that dietary oxidized lipid molecules must be studied before absorption, so as to gain insight into the nature of compounds which are mainly absorbed and available to exert any biological effect in circulatory system and target organs.

2.5.1 Per cent energy from oils in Indian diets

The amount of fat needed by an individual should be able to meet the requirements of essential fatty acids, provide palatability and yet should not produce any adverse effects. It is estimated that about 15-20g of visible fat meets both the requirements of essential fatty acids and 3-6% of the total energy needs. It is recommended, that fat should not exceed than 30%, derived from calories i.e. more than 50 g per day (ICMR, 2002).

The consumption of visible and invisible fats varies in diet of different income group. Diets of high income group (HIG) families have about 10 (en) % of invisible fat provided by cereals, pulses and milk, besides other sources. Visible fat intake is about 16 (en) % which makes it is a total of about 26 (en) %. Invisible fat intake in the middle income group and lower income group is 8 (en) and 6 (en) % respectively while that for the rural population is 8 (en) % (Nigam A, 2000).

Table 2.5.1 shows the composition of some regional meals and it is seen that a south Indian meal has the highest fat content as compared to other regional meals (Nigam A, 2000).

Table 2.5.1: Fat composition of some regional Indian meals

Recipe	Fats (g)
South Indian Meal	28.1
Gujarati Meal	24.5
Bengali Meal	24.8
Punjabi Meal	21.9

Source: Nigam A, 2000

Comparison of past and present diets shows that as the composition of the diet has changed with time, its nutritional quality has deteriorated despite an apparent increase in overall food quantity (Hooper GR, 1999).

Ramachandran P (2008) describes the interstate difference that in most of the states of India, energy intake was higher in rural areas than the urban areas though the differences were not large. In Bihar, Chattisgarh and Assam energy intake was higher among urban population. Energy intake was lower in states like Maharashtra, Tamil Nadu, Karnataka, Gujarat and Madhya Pradesh and higher in Haryana, Punjab, UP and Rajasthan.

In all, states fat consumption was higher in urban areas as compared to rural areas. However, substantial interstate differences were observed in fat intake. Low fat intake in states like Orissa, Chattisgarh and Assam, was observed, which are predominantly rural and have low per capita income; and is higher in the prosperous urbanized states like Gujarat, Haryana and Punjab. Nutrition education aimed at reducing fat intake and health education aimed at improving physical activity are urgently needed in states with high fat and high energy intake to lessen the prevalence of obesity in different age groups including children and women of urban areas (Ramachandran P, 2008).

Recent study by Misra A et al (2011) reported that change in nutrition over the past 30 years (1973–2004), has resulted in a 7% decrease in energy derived from carbohydrates and a 6% increase in energy derived from fats.

In 1998, Beare-Rogers J et al suggested some improvements to the dietary fat in India possibly be accomplished by:

- using oils with moderate levels of linoleic acid, such as groundnut, rice bran, or sesame oil;
- adding an oil or fat with a low level of linoleic acid, such as palm oil, to an oil with a high level of linoleic acid, such as safflower, sunflower, cottonseed, or soya bean oil;
- using a preferred oil along with mustard oil to increase the *n*-3 fatty acid content and moderate the intake of erucic acid from the mustard oil;
- combining soya bean oil with palm oil in equal proportions;
- using oils with minor components, such as antioxidants, which contribute to their nutritional benefits;
- consuming foods rich in *n*-3 linolenic acid, such as some vegetable oils and green leafy vegetables, and (for non-vegetarians) eating fish.

2.5.2 Fried and takeaway food consumption in India and its association with metabolic disorders

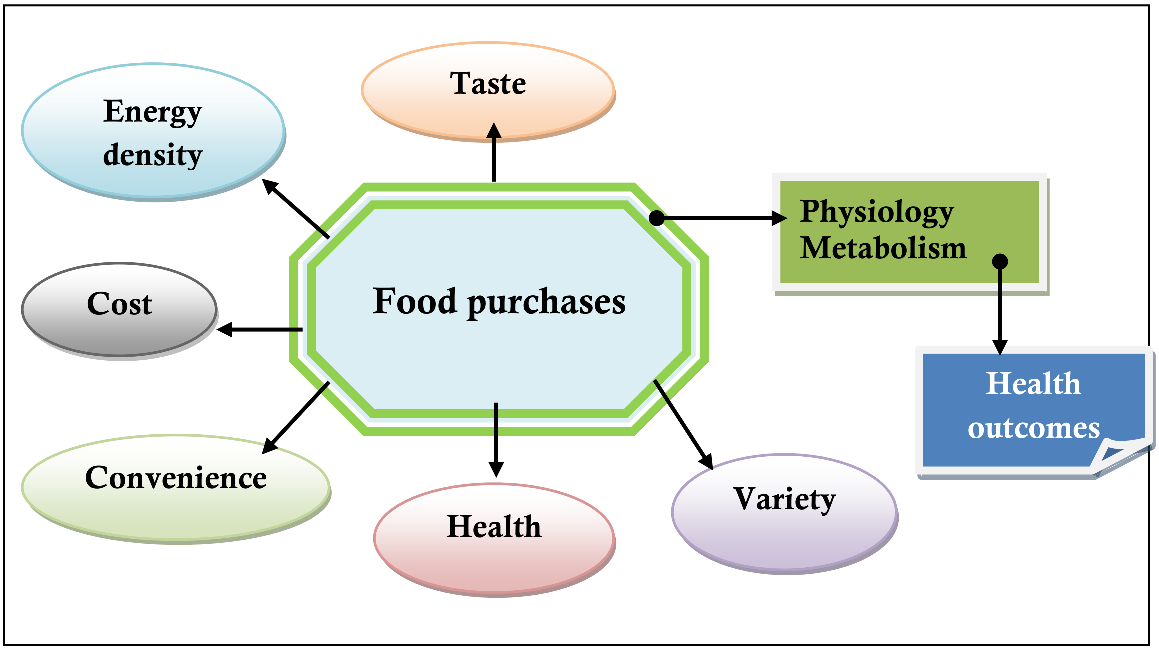
How do people make food choices?

Food choices are made on the basis of taste, cost, and convenience, and, to a lesser extent, health and variety (Glanz K et al, 1998).

Taste refers to the sensory appeal of foods, such as palatability, aroma, and texture. The concepts of taste and energy density are intertwined, because the most energy-dense foods are usually the most palatable and vice versa (Drewnowski A, 1998). Energy density of foods is defined as the energy per unit weight or volume (kcal/100g or mega joules/kg).

Cost refers to the purchase cost/unit of energy (Euros/1000 kcal or dollars/mega joule) or the purchase cost of a daily diet (Euros of dollars/day) (Drewnowski A, 1998).

Convenience refers to the time spent on buying, preparing, and cooking food. Variety refers to the innate drive to secure a varied diet, whereas health refers to concerns with nutrition, chronic disease, and body weight (Drewnowski A, 1998) (Figure 2.5.2.1).



Source: Drewnowski A, 1998

Figure 2.5.2.1: The influences on food purchases: consumer and marketing approach

The fat content of the diet has a clear effect on dietary habits. Fat content influences diet palatability, determines food choices, and appears to have a major influence on food consumption. According to clinical reports, dietary management of plasma lipid disorders is marked by poor adherence to very-low-fat diets; additionally, “cravings” of dieting women for sweet, fat-rich desserts pose a major obstacle to weight reduction (Drewnowski A, 1990).

Subjects in the Women’s Health Trial reported that using little or no fat to flavor foods was among the most difficult health habits to adopt and sustain (Kristal et al, 1992). Additionally, laboratory studies also suggest that energy-dense foods and energy-dense diets have a lower satiating power and may result in passive overeating and therefore weight gain (Drewnowski A and Darmon N, 2005). Away from home foods and restaurant meals are a potential cause of obesity (McCrory MA et al, 1999; Diliberti N et al, 2004).

Fat is a concentrated source of energy that is reinforcing to the hungry organism. High-fat foods have an undeniable sensory appeal, whether innate or learned. Fat makes a diet flavorful, varied, and rich (Drewnowski A, 1992).

Fried food was noted as one of the sources related to a higher incidence of nutritionally linked cancers, especially of the breast, distal colon, prostate, pancreas, ovaries, and endometrium. It also reported that, in 1999, high fat and fried food consumption and low intake of fibers and vegetables comprised about 35% of all main causes of deaths in the USA (Weisburger JH, 2000).

Oxidized oil may comprise a health hazard as a result of the presence of peroxides, aldehydes, ketones, hydroperoxides, polymers, etc. Vitamin E in body membranes is destroyed by peroxides or subsequent free radical reaction. Similarly, polyunsaturated compounds promote oxidation, lowering the tocopherol level. Moreover, polymers formed during deep fat frying have an adverse effect on digestibility (Paul S, Mittal GS and Chinnan MS, 1997).

Dietary assessment of young NIDDM adults revealed about 50% of the subjects consumed fried foods daily in the form of samosa, kachori, manchurian, tikkis etc (Kochhar A, Agarwal V and Sachdeva R, 2010).

A study on 212 male employees of eastern railway (India) revealed that average frequency (number of days in a week) of egg, fried snacks, and Bengali sweets consumption were 5.93, 5.72, and 5.58 respectively (Ghosh A, Bose K and Chaudhuri ABD, 2003).

In India burden of CVD is great and there is evidence of a large increase in nutrition related- non communicable diseases (NR-NCDs). The absolute number of new diabetic cases in India is larger than in any other country of the world. Together, India and China comprise the majority of new cases of diabetes in the world. India's dietary pattern includes very high dairy and sugar consumption and there are marked increases in energy density of the diet, at both urban and rural levels (Popkin BM, 2002).

Diets high in total fat are associated with excess body weight. Diets for weight reduction should be limited in total calories, with ≤30% of total calories as fat to predict a weight loss of 1 to 2 pounds per week (minus 500 to 1000 kcal/d) (Drewnowski A, and Darmon N, 2005).

2.6 FSSAI standards for edible oils

The FSSAI specifications for edible oils are given in Table 2.6. These oils should be expressed from clean and sound seeds. The oils should be clear, free from rancidity, suspended or other foreign matter, separated water, added coloring or flavoring substances, or mineral oil.

Table 2.6: FSSAI specifications for edible oils

Oils	Refractometer reading at 40^{0}C	Saponification value	Iodine value	Polenske value Min.	Free fatty acid Max.%	Bellier test turbidity temperature ^{0}C	Unsaponifiable matter Max.%
Coconut oil	34.0-35.5	Min. 250	7.5-10	13.0	3.0	-	-
Cottonseed oil	55.6-60.2	190-198	98-112	-	1.0	-	1.5
Groundnut oil	54.0-57.1	188-196	85-99	-	3.0	39-41	1.0
Mustard oil	58.0-60.5	168-177	96-110	-	3.0	Max. 27.5	1.2
Olive oil	53.0-56.0	185-196	79-90	-	3.0		1.0
Safflower oil	62.0-64.7	186-196	135-146	-	3.0	Max. 16.0	1.0
Sesame oil	58.0-61.0	188-193	105-115	-	3.0	Max. 22.0	1.5
Soybean oil	61.7-69.5	189-195	120-141	-	1.25	-	1.5
Corn oil	56.7-62.5	187-195	103-128	-	1.0	-	1.5
Almond oil	54.0-57.0	186-195	90-109	-	-	Max. 60	3.0

According to FSSAI specifications, refined vegetable oil is a vegetable oil obtained by expression, neutralized with alkali, bleached with absorbent earth and/or activated carbon, and deodorized with steam. No other chemical agent should be used. The name of the vegetable oil from which the oil has been manufactured should be clearly specified on the label of the container. Refined oils should not contain more than 0.25% free fatty acids and 0.10% moisture by weight. The refined oils should have as light color as possible; be odorless; neutral to taste; and should have good keeping quality. Generally, refined oils are free from moisture and enzyme activity. The deterioration in refined oils is either due to rancidity or flavor reversion (VOPO, 1998).

2.7 History of fried foods

Morton ID (1998) stated "How far back in time, frying with oil goes, it is difficult to tell." However, Stier RF (2004) believed that frying is one of the oldest means for preparing food known to man. Frying supposedly had its origins in China, where foods were pre-cooked prior to roasting. Egyptian wall paintings show dough being fried in oil indicating that Europe and North Africa were using hot oil to cook foods before the time of Christ. Even the Bible has references that could be constructed as an early attempt at frying. The history of frying through the ages is shown in Table 2.7.

Table 2.7: Time line for deep-fat-frying

Year	Event
3000 BC	Chinese fry meat as prelude to roasting
1300 BC	Hebrews fry flat breads
1573	Potatoes introduced in Europe
1600-1700	French fried potatoes is created
1853	Potato chip invented in Saratoga Springs, NY by George Crum
1890's	Potato chip industry begins in US
1897	Hydrogenation of edible oils invented
1906	Commercial oil roasting of shelled peanuts by Planters
1908	J. P. Dushesues founds Leominster Potato chip company
1927-30	Cellophane begins to be used for potato chip bags
1929	Clarence Birdseye develops new commercial freezing technologies
1930-1935	National potato chip Institute warns consumers that chips are not fattening if eaten in small amounts
1938	H.W. Lay Company founds Lay's Potato Chip in Atlanta
1950	Under pan fried cookers introduced
1950-52	Fryers with external heat exchangers with oil circulation introduced; Pork rinds introduced
1953	Simplot scientists develop technique for par-frying potato slices
1961	Frito-Lay merger
1969	Potato chip controversy develops with introduction of Pringles and Chippos
1970-1975	7,000 lb. capacity fryers introduced
1973	1st DGF Symposium-Germany proposes regulations based on oxidized fatty acids for restaurant frying oils
1979	2nd DGF Symposium-Polar materials has index of restaurant frying oil quality
1987	Blumenthal publishes surfactant theory of frying
2000	3rd DGF Symposium-Principle quality index should be sensory parameters of food being fried
2004	4th DFG Symposium

Source: Stier RF (2004)

2.8 Sensory qualities of fried foods

Fats and oils play vital functional and sensory roles in food products. People enjoyed fried foods for thousands of years because of its unique and delicious sensory characteristics. One of the fundamental objectives of frying is to make food more acceptable. Fat is the natural palatable agent *par excellence* (Ghidurus M et al, 2010).

Cooking at high temperatures like frying improves the hygienic quality of the food by inactivation of pathogenic micro organisms; enhances digestibility and bio-availability of nutrient in digestive tract. Besides desirable changes some adverse changes are also involved like loss of heat and oxidation susceptible vitamins and water soluble vitamins (Bognar A, 1998).

Frying in fats brings foods to temperatures above boiling point of water and contributes to the desirable crisp or crunchy textures in fried potatoes or potato chips. Fat makes a diet flavorful, varied, and rich. It is responsible for the characteristic texture, flavor, and aroma of many foods, and largely determines the palatability of the diet. Typically, the first tasting sensation is olfactory perception through the nose or mouth of fat-soluble volatile flavor molecules. Later oral sensations involve the texture and mouth-feel of foods as they change with time, from first bite to complete mastication. Fat-related textures can change from creamy to crunchy or crisp depending on the nature of the food item (Civille GV and Liska IH, 1975).

Cooking end point of fried foods depends on cooking degree of food characterized by the sensory quality attributes namely color, shape, odor and texture. Therefore two points are essential while preparing fried foods:

- formation of attractive and typical surface browning and crust, and of aroma compounds, and
- a certain "inner" cooking degree, reflected by color, taste and texture of the food.

In addition, cooking of the product should reach to optimal degree at the end of frying period with regards to "external appearance and inner cooking degree".

For deep frying there is only one certain point, i.e. a certain temperature of the heating medium at which both internal cooking and browning are reached at one and the same time. The inner cooking degree can be evaluated by measurement of internal temperature of food and browning can be evaluated visually during cooking; which can be classified in to 5 different classes and judged by sensory panelists by judging the degree of browning (Table 2.8) (Bognar A, 1998).

Table 2.8: Assignment of classes and descriptions when judging degree of browning during frying process

Class	Color degree of the surface
A	no browning
B	partly browning, too thin crust
C	optimal browning, golden brownish, shiny as uniform as possible due to product components
D	partly dark brown, a little bit non uniform, some brown-black parts
E	burnt, too dark brown towards the black-brown color

Source: Bognar A, 1998

The most desirable factors for acceptability of fried snack foods are golden-brown surface color, appearance and crunchy texture. The formation of a crust is helped by the presence of starch, which, if it is a constituent of the food product itself, or is added to the food in the form of bread-crumbs and/or batter, dehydrates and therefore allows a quick formation of the crust (Qualia G, Comendador J and Finotti E, 1998). Fried foods that lack these attributes are usually perceived as being of poor quality and will not appeal to the majority of consumers (Mah E and Brannan RG, 2009).

Frying oils degrade with continuous use. A thorough understanding of oil degradation and the effects of degraded oil on the quality of final products is important and the quality of a fried product can be evaluated by appearance, taste and the olfaction (Qualia G, Comendador J and Finotti E, 1998). Therefore, the 3rd German Society for fat Research (DGF) recommended in 2000 symposium that sensory evaluation should be the primary determinant of quality in frying research (DGF, 2000).

2.9 Chemical changes in oil occurring during frying

Frying is a process of immersing food in hot oil with a contact among oil, air, and food at a high temperature of 160^0C to 180^0C. The simultaneous heat and mass transfer of oil, food, and air during deep-fat frying produces the desirable and unique quality of fried foods. Frying oil acts as a heat transfer medium and contributes to the texture and flavor of fried food and prevents sticking of food materials on to the hot surface (Choe E and Min DB, 2007; Sabhiki L and Tiwari BD, 1999).

2.9.1 Morphology of Deep-fat-frying

Deep fat frying is considered to be a moving boundary problem, where a previously nonexistent crust region develops on the food surface and increases in thickness inward during frying while the core region decreases with frying time.

According to Farkas BE, Singh RP, Rumsey TR (1996) and Blumenthal MM (1991) frying can be broken down into four stages:

2.9.1.1 <u>Moisture transfer</u>

The first stage, initial heating, is the period of time during which the surface of the product is heated from its initial temperature to the boiling point of water; this phase is usually short and a negligible amount of water is lost from the food. In this stage heat transfer takes place from the frying medium to the food surface, as soon as the food is immersed in the hot oil. As a result, water from outer surface of the food vaporizes and escapes into the surrounding frying medium. This surface dehydration then forces the water in the interior of the food to move to the outer surface (Blumenthal MM, 1991).

At the food surface, the diffusing water absorbs the latent heat of vaporization from the closest layer of the oil that surrounds the food to form steam. The temperature of the food is only about 100^{0}C, even when the temperature of the frying oil is about 180^{0}C. Moreover, the steam formation at the surface of the food prevents the oil from getting into the interior. So, the food does not burn or char at this stage (Blumenthal MM, 1991; Farinu A and Baik OD, 2005). This suggests that the temperature of the frying oil plays only a smaller role in the thermal damage happening to food materials with high moisture content.

As the interior of the food gradually heats up, some of the lipids present in the food melt and flow out into the oil (Blumenthal MM, 1991). Small quantities of liquefied food materials also flow out of the food into the oil. These flows are collectively called leaching.

2.9.1.2 Fat/oil transfer

The next phase in the process of frying is the oil transfer. Once the diffused water escapes into the oil through the capillaries, the hot oil starts entering into the same open pores and capillaries. The rate of entry of oil into the food is a function of the viscosity and the surface tension of the oil (Blumenthal MM, 1991).

Varela G (1988) reported that the fat penetration starts only after about 60% of the moisture content evaporated in potatoes fried in olive oil. Thus, hot oil acts on the interior of the food material only for a short time, and actual time of contact of oil with the food surface is only about 10% of the total food immersion time, when the frying is done with the fresh oil (Blumenthal MM, 1991).

The amount of oil uptake is directly proportional to the amount of moisture loss. Oil adheres to the food and enters the voids left by moisture that had evaporated. The rate of oil uptake in a deep-fat fried food is initially rapid, but then slows down and approaches a linear relationship with time.

Ni H and Datla AK (1999) showed high initial transfer rate is due to the large difference of oil concentration in the surrounding oil and the initial oil concentration in the food. However, higher initial moisture content in some products (e.g., doughnuts), results in lower fat uptake probably because porosity and initial moisture content are inversely related for a doughnut batter since a batter of higher moisture content has lower leavening acid concentration, which results in less volume expansion (pore formation) and consequently, lower fat uptake during frying (Wheeler FG and Stingley DV, 1963).

Study on high fat content foods revealed that both fat absorption and fat desorption processes occur during frying. In frying beef meatballs, it was reported that fat absorption changed to fat desorption after 60 seconds of frying and at a product temperature of 45.5°C (Ateba P and Mittal GS, 1994).

2.9.1.3 Surface and crust formation

The outer zone of the fried food consists of the crust. The surface, which contributes to the initial visual impact, generally has an even, golden brown color resulting from browning or Maillard reaction.

The content of reducing sugars is related to the final color of the fried product, *i.e.* the higher content of sugars, the darker tone is expected in potato products such as french fries, potato chips and others. Moreover, potatoes high in sugar taste sweet and have a poor/soft texture after cooking. This poor texture may probably be related to the low starch levels associated with the high sugar content. Starch provides the most important contribution to the texture of processed potatoes (Miranda ML and Aguilera JM, 2006).

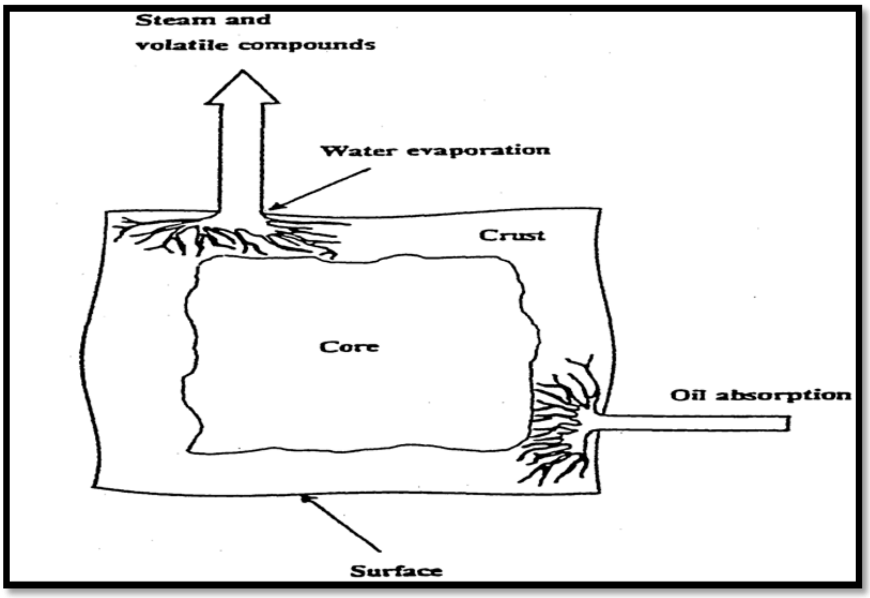
The duration and the temperature of frying, in combination with the chemical composition of the food, that influence the degree of browning, rather than the type of frying oil used (Stevenson SG, Vaisey-Genser M and Eskin NAM, 1984).

The crust formation, which is one of the most palatable characteristics of the fried food, was greatly influenced by fat penetration kinetics (Varela G, 1988). The heat from the frying medium drove the cellular or capillary water out from the food material. Guillaumin R (1988) described that leaching out of this water/dehydration cause this crust formation with numerous cavities, pores, and larger surface. The frying medium then started diffusing into the capillaries and pores in the crust. The phenomenon of crust formation can be observed for about 3 to 6 min. The majority of the oil absorbed was located in the crust and the outer zone of the fried product. The moisture content of the crust was about 2 to 3% and the oil content was 8 to 10% for french fried potatoes.

When a product is removed from the fryer, the viscosity of the oil at its surface increases due to a fall in temperature which makes oil difficult to drip off the product's surface and the bulk of the oil moves into the crust due to capillary and gravity formed as result of moisture loss. Keller C et al (1988) studied oil intrusion into fried potatoes using an oil soluble dye and found that oil penetrated no further than the surface crust layer.

2.9.1.4 Cooking of the interior

In the final phase of cooking, the moist inner zone or the core gets cooked. The core may not be observed in thin products like potato chips, due to the overlapping of crusts from both sides. The cooking of the core is mainly due to the heat penetration rather than the oil penetration or absorption (Stevenson SG, Vaisey-Genser M and Eskin NAM, 1984). Figure 2.9.1.4 shows the cross section structure of a typical fried food.



Source: Paul S, Mittal GS and Chinnan MS, 1997

Figure 2.9.1.4: Structure of the cross section of a typical fried food

2.9.2 Factors affecting oil penetration and absorption by the food

Foods high in initial fat content do not absorb oil during frying in fact; food fat is leached out into the oil. The important factors affecting oil penetration into the food products are described by Guillaumin R in 1988, as follows:

2.9.2.1 <u>The geometrical shape of the food products</u>

The geometrical shape, that is, the ratio of surface area of the product to its volume plays an important role in the oil penetration. For example, the French fried potato contained only 13.5% oil on an average, whereas the fried potato chip contained about 40% oil, because the surface area of potato chip was 10 to 15 times greater than that of the french fried potato for the same volume (Guillauman R, 1988).

Goni I et al (1997) reported thickness of chips is an important factor affecting the overall fat content of hot chips. Cracks and rough surfaces increase the surface area and thus increase the fat absorption. Thick-cut chips (12 mm or bigger) absorb less fat than thin cut chips. The fat content in chips decreased with increasing cross-section at area of potato sticks, and fat is restricted to the surface of the sticks (Keller C et al, 1990).

2.9.2.2 Viscosity of the frying oil

Viscosity of the frying oil is an important factor determining the total volume of oil sticking to the large cavities in the crust of the food product. Higher viscosity provided a larger volume of oil on the fried food. Potatoes absorbed about 8.5% of oil when fried in fresh oil, and it increased to 15% in degraded oil due to increase in viscosity (Guillaumin R, 1988).

Study by Yamsaengsung R and Moreira RG (2002) reported higher cooling temperature results in low oil viscosity and thus low adhesion between oil and product and more of the oil runs off the surface of the product.

Frying of potato chips in soybean oil and partially hydrogenated vegetable oil for 80 h intermittently showed an increase in periodic in viscosity, influenced by frying temperature rather than frying medium (Tyagi VK and Vasishtha AK, 1996).

2.9.2.3 Specific gravity of the food

Generally, the oil absorption decreases as the specific gravity of the food increases. An increase in specific gravity of the food generally means an increase in the moisture content. Higher moisture content produces larger quantity of steam, which reduces the oil-to-food contact time (Guillauman R, 1988).

In a study by Tyagi VK and Vasishtha AK, 1996 reported *vanaspati* (partially hydrogenated vegetable oil) used for frying potato chips intermittently for 80 h had lowest specific gravity as compared to soybean oil with different levels of antioxidants, irrespective of frying temperature and duration of frying.

2.9.2.4 Type of food

Fedeli E in 1998 reported that foods are not pure chemical products; they are a mixture of chemical components classified as lipids, proteins, sugars (starch) and minor components ascribable to various chemical classes. Variability of the components of each class gives rise to many alternatives that are important for frying process. For instance lipids vary in saturation, physical characters, and chemical behavior which may act as a solubilizer of many minor components. Proteins vary in the physical and chemical characters because of their constituents amino acids; they show free reacting groups which are present in food originally or batter created during the cooking process. Starch has high degree of active centers, usually OH, CH and NH. Thus their physical and chemical characteristics vary strongly as a function of the polymerization degree that varies also during the cooking operations.

The textural properties, porosity, size, and orientation of capillary spaces, etc. are differ from one food to another. This makes the oil penetration characteristically different from food to food (Guillauman R, 1988).

Absorption of nonglyceride components such as nutraceuticals/antioxidants or other related phytochemicals also may have a selective distribution between oil and the batter coated products during deep frying, more so when the product has many other components such as starch, carbohydrates, and protein (Nasirullah and Rangaswamy BL, 2005). In study, oil absorption can be reduced by coating of whey protein isolate as a post breading dip in deep fried battered and breaded chicken patties (Mah E and Brannan RG, 2009).

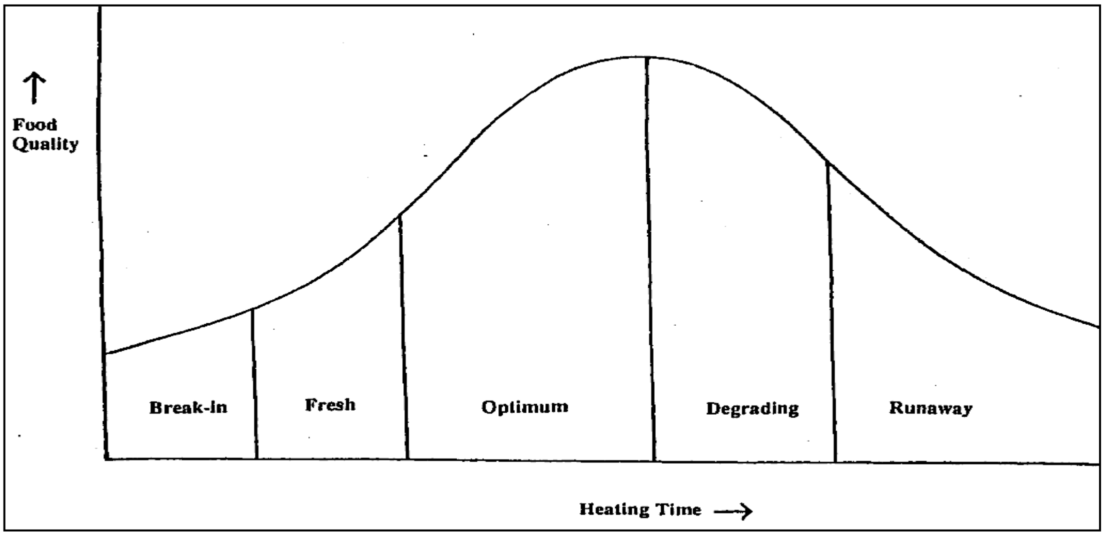
2.9.2.5 Temperature of the frying medium

Varela G (1988) established that the frying oil temperature in a range of 150 to 180°C has no significant effect on oil absorption by foods. Oil absorption decreases with a higher frying oil temperature of 180 to 200°C. However, this temperature range is not usually accepted in frying operations.

Yamsaengsung R and Moreira RG (2002) reported that the temperature, at which food is cooled after frying, has the largest effect on oil absorption and higher cooling temperatures lead to lower oil absorption, known as cooling temperature.

2.9.2.6 Time of frying

The oil absorption by the food increases with longer durations of frying. Frying oil quality curve shows the quality of the fried potato as a function of frying oil stages, as the frying operation proceeds. Frying oil quality curve is described by Blumenthal MM in 1991 is shown in Figure 2.9.2.6.



Source: Blumenthal MM, 1991

Figure 2.9.2.6: Frying oil quality curve showing the five phases that frying oil passes through during the degradation process

The changes occurring in food quality with the advancement of heating of oil are described as follows:

1. ***Break-in oil***- White-colored product; raw, ungelatinized starch at the center of the fry; no cooked odor; no crisping of the surface; and little oil absorbed by the food.

2. ***Fresh oil-*** Slight browning at the edges of the fry; partially cooked (gelatinized) centers; crisping of the surface; and slightly more oil absorption.

3. ***Optimum oil-*** Golden-brown color; crisp, rigid surfaces; delicious potato and oil odors; fully cooked centers (rigid, ringing gel); and optimal oil absorption.

4. ***Degrading oil-*** Darkened and/or spotty surfaces; excess oil pickup; product moving toward limpness; and case-hardened surfaces.

5. ***Runaway oil***- Dark, case-hardened surfaces; excessively oily product; surfaces collapsing inward; centers not fully cooked; and off-odor and-flavors (burned).

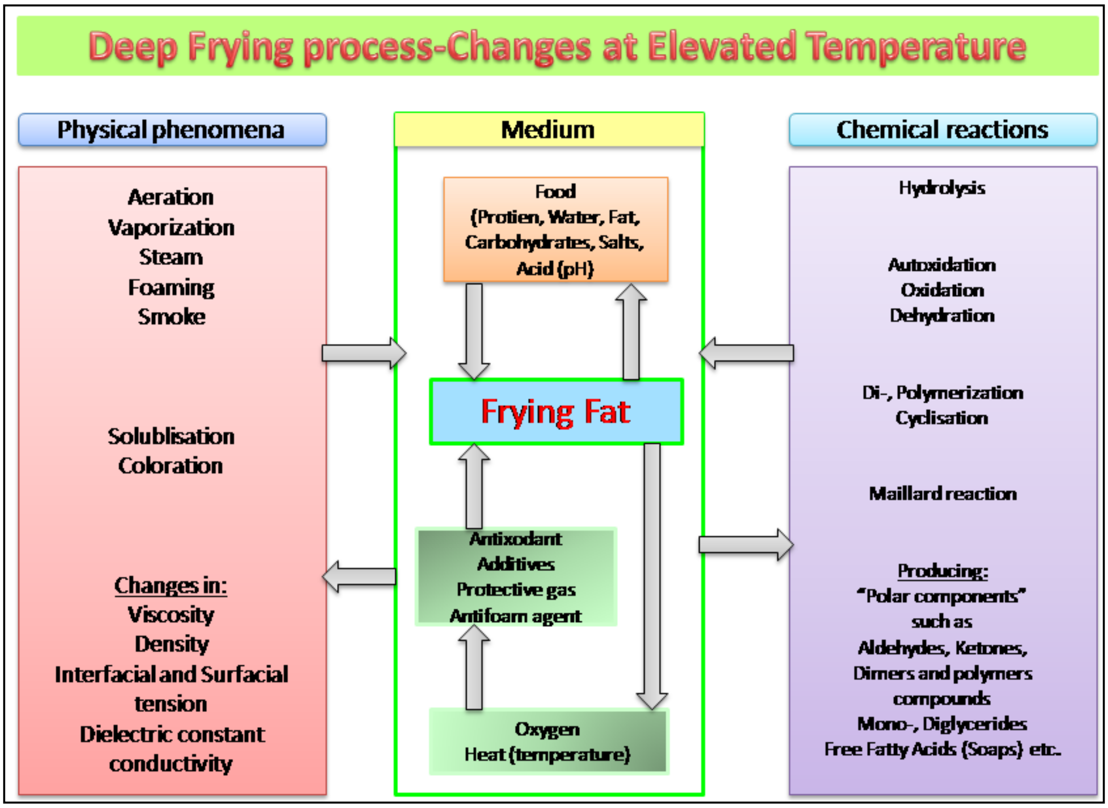
2.9.3 Chemistry of deep-fat- frying/fat degradation

Frying is the combination of prolonged heating and high temperature in the presence of moisture and oxygen causes an interrelated series of reactions takes place (Figure 2.9.3.1) and the physical and chemical changes taking place shown in Table 2.9.3.1.

Table 2.9.3.1: Effects of physical and chemical reactions during deep fat frying

Physical changes:
Increased viscosity, color and foaming Decreased smoke-point
Chemical changes:
Increased free fatty acids, carbonyl compounds and high molecular weight products, decreased unsaturation, flavor quality and nutritive value (e.g. from essential fatty acids)

Source: Podmore J, 2002

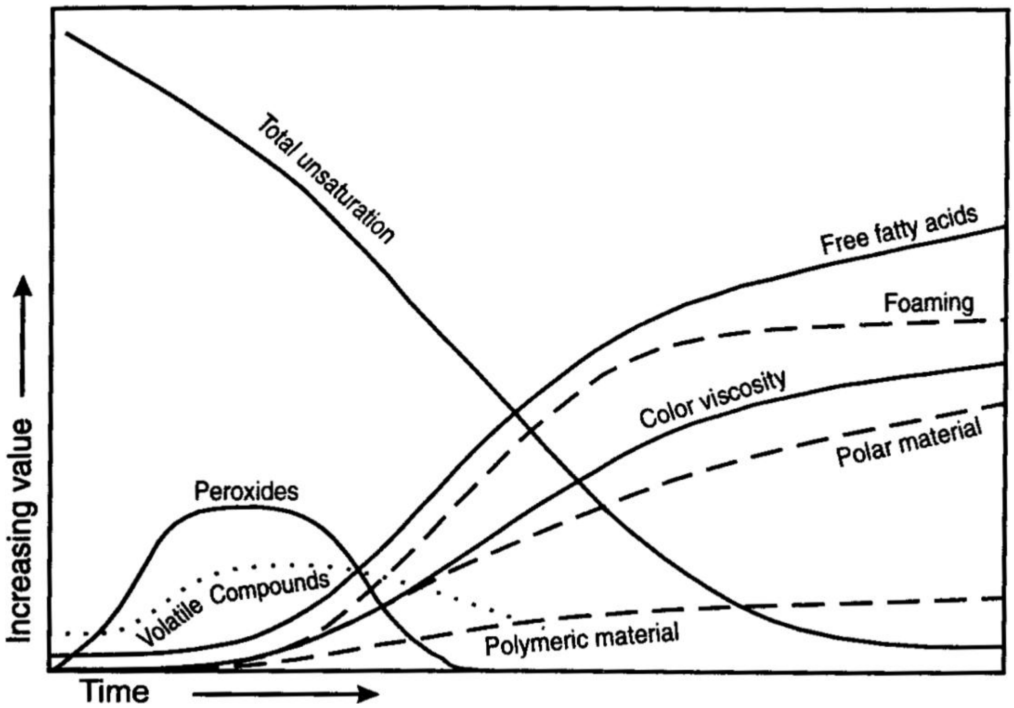


Source: Gertz C, 2000

Figure 2.9.3.1: Scheme of the influence of the deep-frying process

During frying hundreds of complex chemical reactions takes place in the oil and it gets chemically altered during frying. More than 400 different chemical compounds have been identified in deteriorated frying oils. The products of degradation can generally be divided into two main groups, namely, volatile and non-volatile products (Figure 2.9.3.2).

A portion of the volatile products escapes into the atmosphere with steam, while the rest remains in the oil and may undergo further alterations or get consumed by the fried food. Some of the volatile compounds contribute to the flavor of the fried food products. The degradation products can be detrimental to the oil and food as well as making the flavor more attractive (Choe E and Min DB, 2007; Paul S, Mittal GS, and Chinnan MS, 1997).



Source: Choe E and Min DB, 2007

Figure 2.9.3.2: Changes in volatile and nonvolatile decomposition products during the frying process

The non-volatile degradation products are shown in Table 2.9.3.2 which remains in the oil, promoting further degradation. They are responsible for the changes in the physical properties and the various analytical indices of the oil (White PJ, 1991).

Table 2.9.3.2: Volatile and nonvolatile degradation products from frying oil

Nonvolatile products	Volatile products
Monoglycerols	Hydrocarbons
Diglycerols	Ketones
Oxidised triacylglycerols	Aldehydes
Triacylglycerol dimers	Alcohols
Triacylglycerol trimers	Esters
Triacylglycerol polymers	Lactones
Free fatty acids	

Source: Lawson H, 1997

2.9.3.1 Changes during frying oil degradation

The thermal degradation of frying oil is complex, with many variables shown in Table 2.9.3.1.

Table 2.9.3.1: Factors affecting oil degradation

Oil or food factors:
❖ Unsaturation of fatty acids
❖ Type of oil
❖ Type of food
❖ Metal in oil or food
❖ Initial oil quality
❖ Degradation products in oil
❖ Antioxidants
❖ Antifoaming agents
Process factors:
❖ Oil temperature
❖ Frying time
❖ Aeration or oxygen absorption
❖ Frying equipment
❖ Continuous or intermittent heating or frying
❖ Frying rate
❖ Heat transfer
❖ Turnover rate[a]; addition of makeup oil
❖ Filtering of oil or frying vessel/fryer cleaning
[a] Turnover is the ratio of the volumetric capacity of the fryer to the rate at which fresh frying oil is added to replenish the fryer

Source: Podmore J, 2002

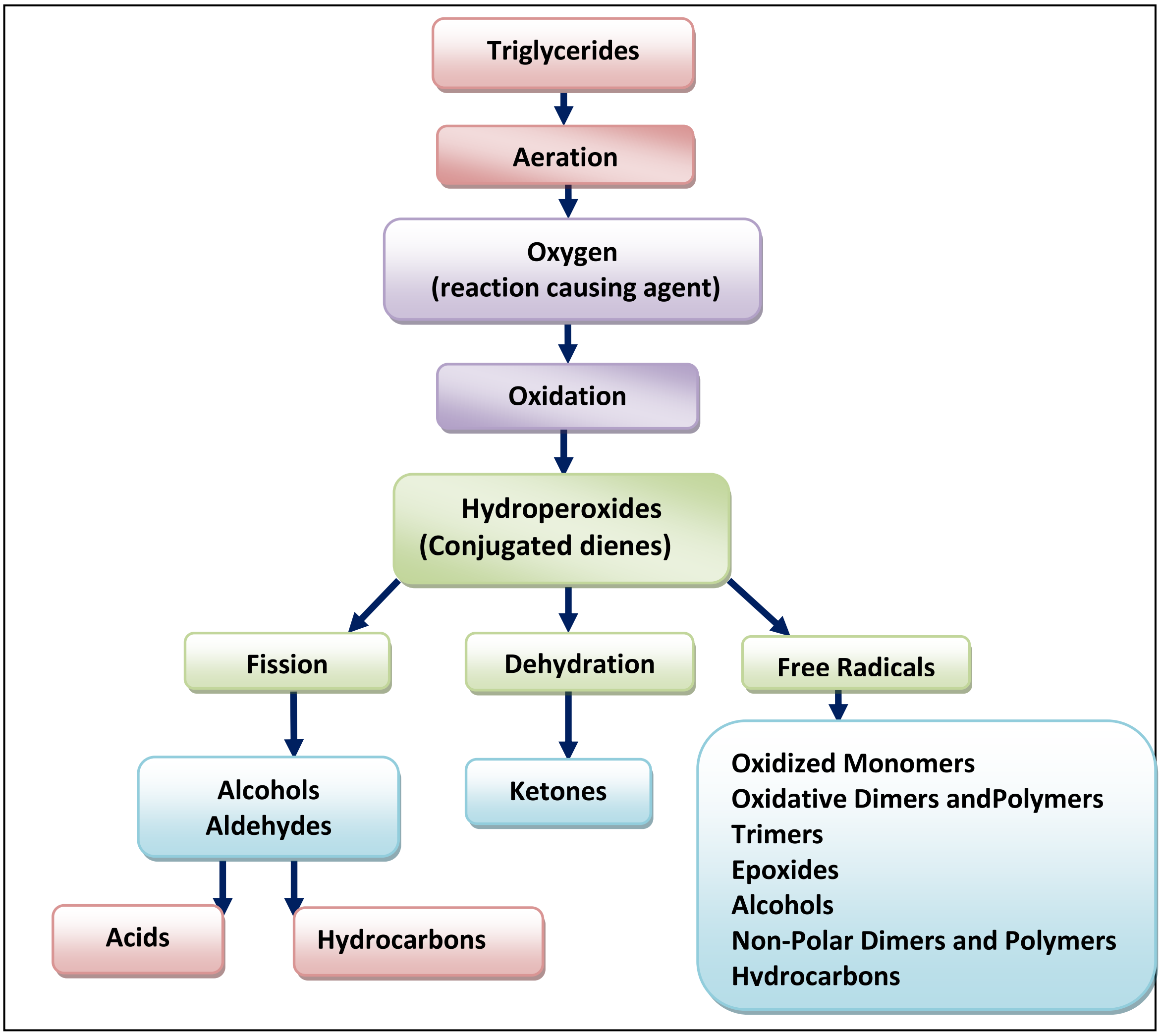
Above given factors affect oil by: **hydrolytic alteration caused by moisture, oxidative alteration caused by oxygen, and thermal alteration caused by heat** (White PJ, 1991)**.** These all contribute to the breakdown of fats. During frying there is an increase in saturation of fatty acids, breakdown products are formed and there are texture, color and flavor changes. Other changes include, an exchange of substances between the food and the fat with the food absorbing fat and breakdown products, proteins, and other substances released into the fat.

2.9.3.1.1 Oxidation

Oil oxidation is inevitable it involves release of moisture, elevated temperature and exposure of oil to atmospheric oxygen during frying favor oxidation of the frying medium. Figure 2.9.3.1.1 shows a schematic diagram of oxidative alterations. Oxidation may be auto oxidation or thermal oxidation.

i) **Auto oxidation:** The reaction of the atmospheric oxygen with fat molecules at room temperature is known as auto oxidation.

ii) **Thermal oxidation:** The process taking place when oil is heated at high temperature in presence of oxygen is termed as thermal oxidation.



Source: Paul S, Mittal GS and Chinnan MS, 1997

Figure 2.9.3.1.1: An overview of fat aging

Oxidation can be described as comprising three sub-processes, which produce a variety of decomposition compounds known as: **primary, secondary and tertiary oxidation.**

Primary oxidation caused by the reaction of oxygen with oil at high temperatures, leading to formation of hydroperoxides bound to a double bond of an unsaturated fatty acid. The first degradation is the '*fission*', which produces smaller molecules which cross-link together to form monomers and dimers (alcohols, aldehydes, acids, and hydrocarbons). High temperature accelerates oxidation. **Peroxide value** is a simple common test to determine the quality of fresh oil, but quite insignificant for frying processes, since peroxides are volatile at high temperatures. Peroxide value indicates oxidation reactions occurring after frying and characterizes the sampling rather than the oil quality during the process (Dana D and Saguy S, 2001).

Secondary oxidation, fission of hydroperoxides at high temperatures leads to the second degradation known as '*dehydration*'. This forms secondary oxidation products like alcohols, carbonyls and acids. Unsaturated aldehydes can undergo auto oxidation giving rise to dialdehydes such as malondialdehyde (MDA). A common method for measuring aldehyde concentration is the **p-anisidine value**, which enables colorimetric determination of aldehyde concentration. It also provides a criterion that could be correlated with the organoleptic quality of the fried product (Kock Wai TN, 2007). Decomposition of fatty acids from triglycerides results in the formation of small and large molecules. Small molecules are generally volatile and large are generally non-volatile decomposition products. Volatile decomposition products are responsible for the unique and characteristic taste of fried products (Dana D and Saguy S, 2001).

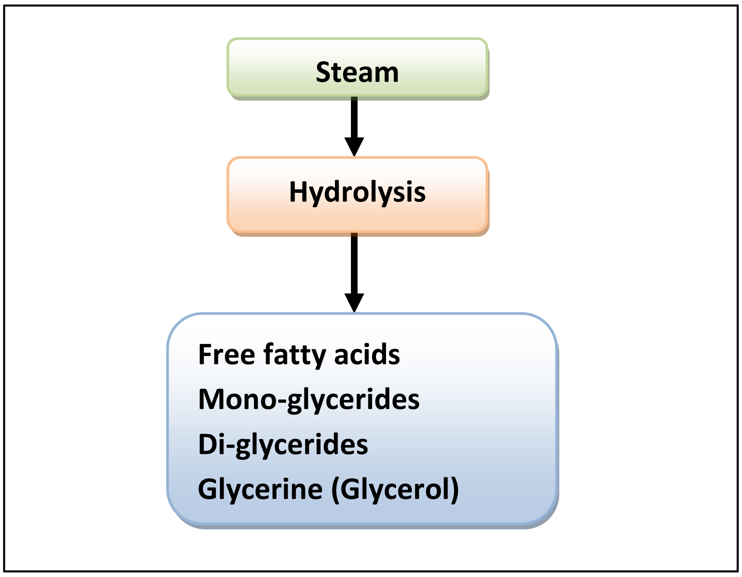
Tertiary oxidation also known as third degradation or '*free radical formation*', which produces oxidized monomers, oxidative dimmers and polymers, trimers, epoxides, alcohols, hydrocarbons, non-polar dimers, and polymers which are harmful to human health (Stevenson SG, Vaisey-Genser M and Eskin NAM**,** 1984)**.** This process increases oil viscosity, the color turns darker and brown layers appear on the surface. Most of the decomposition products are formed by the free radical chain reactions. The rate of these reactions increases with higher concentrations of oxygen and free radicals (Gere A, 1983). Polymerization **is abundant mainly in oils rich in free unsaturated fatty acids, such as soybean oil** (Dana D and Saguy IS, 2001)**.**

Blumenthal MM (1991) reported the basic theory of frying that materials which affect the heat transfer at the oil-food interface act to reduce the surface tension between the two immiscible materials and are referred as surfactants. Only a small amount of oxygen is introduced into the oil at low concentrations of surfactants. As the interfacial tension is high at low concentrations of surfactants, the steam bubbles readily break and form a blanket of steam over the oil surface, reducing the contact of atmospheric oxygen with the oil. At moderate surfactant concentrations, oxygenation forms a number of chemicals. They include oxidized fatty acids, which produce good heat transfer properties in the oil and desirable volatile compounds. However, at high concentrations of surfactant materials, oil degradation dynamics and kinetics are forced to form short-chain fatty acids because of the high availability of oxygen. Flammable ketones and ethers are formed at this stage.

As oil degrades the specific gravity increases, heat capacity, and surface tension decrease and contact time between the oil and the food increases causing changes in heat transfer. Volatile and non-volatile decomposition products are formed, free fatty acid content increases, iodine value decreases, fat darkens, strong flavors develop, the smoke point is lowered and there is increased foaming and viscosity (Saguy IS and Pinthus EJ, 1995; Blumenthal MM, 1991). It is suggested that potentially harmful compounds may be formed in the food (Whero F and Birch J, 1997).

2.9.3.1.2 *Hydrolysis*

De-esterification reaction leads to cleavage of bonds between glycerol and fatty acids. When food is fried in heated oil, the moisture forms steam, which evaporates with bubbling action and gradually subsides as the food are fried. Water, steam, and oxygen initiate the chemical reactions in the frying oil and food. Water, a weak nucleophile, attacks the ester linkage of triacylglycerols, and produces di- and monoacylglycerols, glycerol, and free fatty acids. Free fatty acids contents in frying oil increases with the number of frying (Figure 2.9.3.1.2). Thermal hydrolysis takes place mainly within the oil phase rather than water-oil interface (Lascaray L, 1949). Hydrolysis is more preferable in oil with short and unsaturated fatty acids than oil with long and saturated fatty acids because short and unsaturated fatty acids are more soluble in water than long and saturated fatty acids. Water from foods is easily accessible to short-chain fats and oils for hydrolysis (Nawar WW, 1969).



Source: Paul S, Mittal GS and Chinnan MS, 1997

Figure 2.9.3.1.2: Schematic diagram of hydrolysis

Large amount of water hydrolyze the oil rapidly than steam. Large contact between the oil and the aqueous phase of food increases hydrolysis of oil. The amount of free fatty acids formed is directly proportional to the amount of steam released by the food into the fat (Lawson H, 1997; Dana D, Blumenthal MM and Saguy IS, 2003).

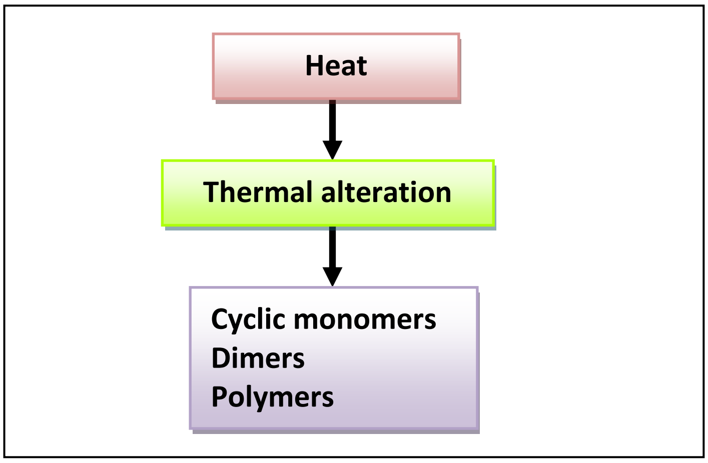
In a study by Houhoula DP, Oreopoulou V and Tzia C (2002) reported that mono-and diacylglycerols in cottonseed oil during frying of potato chips at 155^0C to 195^0C increased initially and then reached a plateau. Further, study by Romero A, Cuesta C and Sanchez-Muniz FJ (1998) revealed frequent replacement of frying oil with fresh oil slows down the hydrolysis of frying oil.

Frega N, Mozzon M and Lecker G (1999) reported that free fatty acids and their oxidized compounds produce off-flavor and make the oil less acceptable for deep-fat-frying. Di- and monoacylglycerols, glycerol, and free fatty acids accelerate the further hydrolysis reaction of oil. Glycerol evaporates at 150^0C and the remaining glycerol in oil promotes the production of free fatty acids by hydrolysis (Naz S et al, 2005).

Determination of free fatty acids (FFA or acid value) concentration is often used as a criterion for oil quality during frying and some countries are implementing it as an upper measure for oil acceptability for frying. Japan Ministry of Health and Welfare recommended 2.5mg/g acid value as the upper limit in frying oil.

2.9.3.1.3 Polymerization

At elevated temperatures, when the oxygen supply is rather limited, the main reactions lead to polymerization rather than oxidation (Figure 2.9.3.1.3). Due to oxidation and thermal alteration, products undergo polymerization forming gums and resins. Polymerization results in brown residues near the heating elements. Polymers formed in deep-fat frying are rich in oxygen. Thermal changes lead to the formation of cyclic monomers, dimers and polymers in a non-radical mechanism. Dimers and polymers are large molecules with a molecular weight range of 692 to 1600 daltons. Polymerized triglyceride formation is proportional to the temperature, frying time and less dependent on fatty acid composition. Saturated fatty acids are more stable than unsaturated counterparts but at temperatures over 150^{0}C they decompose to carboxylic acids and a large variety of aldehydes, ketones, and other carbons (Gertz C, Klostermann S and Kochhar SP, 2000).



Source: Paul S, Mittal GS and Chinnan MS, 1997

Figure 2.9.3.1.3: Schematic diagram of thermal alterations

The linoleic acid (polyunsaturated) present in fat is conjugated by heat. It may then cyclise within itself or another molecule containing a double bond to form a six member cyclic compound. The double bond of cyclohexane ring reacts with conjugated linoleate to form a trimer (Diels O and Alder K, 1928).

Formation of polymers during frying in oil bring some changes like increase in viscosity, density, development of dark color, decrease in iodine value and surface tension and an increased foaming tendency of oil (White PJ, 1991).

2.9.3.2: <u>Interrelation of Hydrolytic, Oxidative and Thermal alterations</u>

The hydrolytic, oxidative, and thermal alterations are interrelated as well as superimposed. For an instance, both oxidative, non-oxidative dimers and polymers are formed at high temperature of frying. Both hydrolysis and oxidation of double bonds result in free fatty acids formation in the frying oil. Furthermore, volatile compounds such as ketones, aldehydes, alcohols etc. resulting from oxidation are volatilized and liberated into the atmosphere by steam that is responsible for the hydrolysis. As a result of oxidative and thermal alterations polymers are formed and cause foaming, consequently the steam bubbles are trapped longer in the oil to accelerate hydrolysis. Formation of steam plays an important role in reducing oxidative alterations by forming a blanket over the oil surface (Blumenthal MM, 1991).

Nawar WW (2000) reported that food can leach fat during frying, resulting in different mixture stability compared to the original frying oil. The presence of food crumbs and batter residues contributes to color changes.

2.9.3.3 Polar and non-polar fractions of deteriorated oil

The non-polar fraction mainly consists of all the unaltered triglycerides. Very small amounts of trimers and non-polar dimers also contribute to this fraction (Lumely ID, 1988).

Polar fractions are collectively known as all the degradation products other than non-polar fraction. They are also called **'total polar materials'** or **'total polar artifacts'**. All the polar materials refer to polar material present in oil, as well as those due to contamination from food materials. Leaching of fat from meat products and other present compounds in oil are also responsible for degradation of frying oil together with formation of polar materials (Paul S, Mittal GS and Chinnan MS, 1997).

In terms polar compounds quality of used frying fats and oils was studied by Dobarganes MC and Marquez-Ruiz G (1998) from three different frying sectors: domestic use, restaurants and fried-food outlets and industrial frying. The finding of the study is shown in Table 2.9.3.3.1.

Table 2.9.3.3.1: Polar compounds (PC) in used frying fats from different sources

	Discontinuous Fryers		Continuous fryers
	Domestic use	**Restaurants and fried food outlets**	
Number of samples	72	190	82
Polar compound range (wt %)	10.5-42.1	3.1-61.4	4.2-27.3
Number of samples with PC >25%	24	69	3

Source: Dobarganes MC and Marquez-Ruiz G, 1998

Paul S, Mittal GS and Chinnan MS (1997) classified polar fraction according to their molecular weights and relative polarities into polymers and decomposition products listed in Table 2.9.3.3.2. **Polymers** refer to the group of all the degradation products with molecular weight higher than that of triglycerides. **Decomposition products** refer to the group of all the degradation products with molecular weights less than that of triglycerides.

Table 2.9.3.3.2: Classification of degradation products

Major fractions of chemical degradation	Components forming the Fractions
Polymers (low polarity)	Highly polymerized materials Trimers Dimers
Triglycerides (neutral)	Triglycerides
Decomposition products (high polarity)	Diglycerides Monoglycerides Free fatty acids Cyclic monomers Non-cyclic monomers Volatile compounds

Source: Paul S, Mittal GS and Chinnan MS, 1997

2.9.3.4 *Trans* isomers

Edible fats and oils vary in their triglyceride makeup, relative degree and forms of unsaturation (*cis* and *trans*), weight-average molecular weight, and overall fatty acid composition/distribution, and these complex determinants define the physico-chemical properties of the lipid system. For stability and functionality reasons, oils are often hydrogenated and converted into fats, this increase the concentration of *trans* isomers (Voort ven de FR, Sedman J and Ismail AA, 1997).

Chemically, *trans* fat refers to a lipid molecule, that contains one or more double bonds in trans configuration. A double bond may exhibit one of two possible configurations; *trans* or *cis*. In *trans* configuration, the carbon chain extends from opposite sides of the double bonds, rendering a straighter molecule, whereas in *cis* configuration, the carbon chain extends from the side of the double bond, rendering a bent molecule (Mudgil D, Barak S and Khatkar BS, 2010).

Fatty acids found in foods can be saturated (no double bonds), monounsaturated (one double bond) or polyunsaturated (more than one double bond). The double bonds provide rigidity to the molecule and result in specific molecular configurations. Naturally occurring fatty acids in foods usually have the *cis* configuration, i.e. the hydrogen atoms with respect to the double bond are on the same side of the molecule (Figure 2.9.3.4).

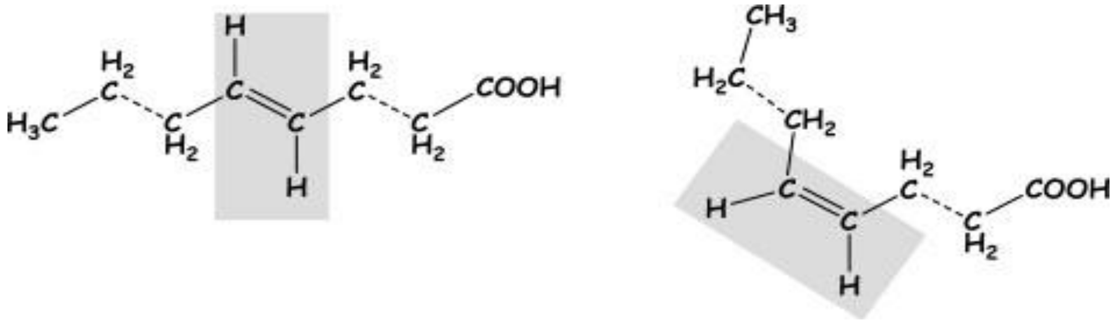


Figure 2.9.3.4: ***Trans*** **(left) and** ***cis*** **(right) geometrical configuration**

Two double bonds may be "methylene interrupted" (MI) meaning separated by a methylene (-CH2-) group, or "non-methylene interrupted" (NMI), i.e. separated by several methylene groups, or "conjugated", means separated by only a single carbon-carbon bond. Among fatty acids with conjugated bonds, conjugated isomers of linoleic acid called conjugated linoleic acids (CLA). Theoretically, these could include 14 positional isomers from Δ2,4- to Δ15,17-18:2, and each having either a *c*,*c*, *c*,*t*, *t*,*c*, or *t*,*t* configuration, for a total of 56 isomers (Ledoux M, Juaneda P and Sebedio JL, 2007).

The consumption of deep-fried foods, hydrogenated fats and baked food items are major sources of *trans* fats. In developed countries like Europe and North America, average population *trans* fatty acid (TFA) consumption has varied between 2 and 4% energy (%E), or between 5 and 10g/day in an average 2000 kcal/day diet. Estimation by food frequency questionnaires of average per capita TFA intake in North America was 3-4g/day. However, TFA concentration in human milk was 10g/day. In Australia, per capita estimates ranged from 3 to 8g/day. However, population consumption estimates in traditional diets of Asian countries was much low, 0.6g/day in Korea and 0.1-0.3g/day in Japan (Craig-Schmidt MC, 2006).

In Western European countries, mean per capita TFA intake in men was lowest in Greece, Italy, Portugal, and Spain (1.2-2.1 g/day); intermediated in Finland, Germany, France, the United Kingdom, Denmark, and Sweden (2.4-3g/day) and in Belgium, Norway, and the Netherlands (4.4-4.8g/day); and highest in Iceland (6.7g/day) (Hulshof KF et al, 1999; van Poppel G, 1998).

Studies on TFA consumption in developing countries revealed that use of partially hydrogenated vegetable oil (PHVO) in Iran was extensive for house hold cooking in rural and less educated regions (overall average TFA intake was 12.4g/day; ~4.2%E). Similarly in India, PHVO use for cooking in form of *vanaspati* is popular in various regions (Mozaffarian D et al, 2007; Ghafoorunssia G, 2008).

Review by Teegala SM, Willet WC and Mozaffarian D (2009) compiled TFA consumption effects on numerous adverse risk factors responsible for chronic disease, systemic inflammation, endothelial dysfunction insulin resistance and adiposity shown in Table 2.9.3.4.

Table 2.9.3.4: Adverse effects of dietary trans fatty acids on risk factors for chronic disease

Risk factor	Evidence for effects of dietary trans fat
Inflammation	Increased tumor necrosis factor activity, interleukin-6, C-reactive protein
Endothelial dysfunction	Increased plasma E selection, soluble intercellular adhesion molecule-1, soluble vascular cell adhesion molecule-1 Decreased brachial artery flow mediated dilation
Blood lipids and lipoproteins	Increased total/HDL-cholesterol ratio, total cholesterol, LDL-cholesterol, apolipoprotein B, triglycerides, lipoprotein (a) Decreased HDL-cholesterol, ApoA1, LDL particle size
Insulin resistance and diabetes	Increased insulin resistance in animal experiments No significant effects on glucose-insulin markers in short-term trials among lean, healthy individuals Association with incident (new-onset) type 2 diabetes
Weight gain and obesity	Increase in weight gain due to increased visceral fat

Source: Teegala SM, Willet WC and Mozaffarian D, 2009

2.9.4 Characteristics of oils for frying

Food oils and fats enter into three major areas of food preparation: a) food processing plants, b) food service kitchens, and c) the home. Therefore the performance characteristics of oils and fats in these three areas are of prime concern (Lawson H, 1997). The inherent stability of different vegetable oils used for frying purpose is provided in Table 2.9.4.

Table 2.9.4: Inherent stability of oils use in frying

Rating	Fat and oil source	Inherent* oxidation stability	PUFA oxidizability#	Calculated Iodine value
Worst	**Safflower oil**	8.0	78.5	146.1
	Sunflower oil	7.1	69.1	135.3
	Soybean oil	7.1	66.9	133.0
	Corn oil	6.5	62.0	128.4
	Cottonseed oil	5.8	55.8	112.6
	Canola oil	4.5	38.6	113.0
	Peanut oil	3.7	32.0	97.1
	High oleic sunflower oil	1.7	9.0	85.6
	Olive oil	1.6	7.7	82.4
	High oleic safflower oil	1.6	7.4	83.3
	Palm oil	1.5	10.9	52.4
	Palm kernel oil	0.4	2.3	17.2
	Coconut oil	0.2	1.6	8.1
Best	**Milk fat**	0.7	4.0	34.0

***Inherent stability calculated from decimal fraction of fatty acids multiplied by reaction rates with oxygen, assuming rate for oleic acid as 1, linoleic acid as 10 and linolenic acid as 25.**

 # PUFA oxidizability is the sum of PUFA times the active methylene group (% C18:2 X 1) + (% C18:3 X 2), etc.

Source: Jana AH et al, 2011

***<u>Coconut and Palm kernel oil</u>*:** The lauric oils (Coconut, Palm kernel) stand apart in the world of oils and fats. Lauric fatty acid rich oils are unsatisfactory as frying oil since they contain large proportion of lauric acids and other fatty acids with fewer than 14 carbon atoms. These fatty acids are quite volatile and can cause excessive smoke development during frying. These are very oxidative stable and have a melting point slightly above ambient temperature. These two lauric oils differ slightly from one another in that coconut oil is richer in the C6:0 to C10:0 acid and Palm kernel oil is richer in unsaturated C18 acids (Pantzaris TP and Basiron Y, 2002). Coconut oil is used as frying medium where there is local preference i.e. Southern India or if the flavor attributes of coconut oil are desirable e.g. for banana chips.

***Palm oil*:** It is widely produced semi-solid oil and does not pose problem of smoke during frying as does Palm kernel oil. It has the advantage of being low in PUFA (10%) and low Iodine value (IV) and consequently has good heat and oxidative stability. It has high (~42.5%) oleic acid content. Its high proportion of saturated fatty acids (SFAs) may be disadvantageous from nutritional point of view and may result in solidification in pipes and during storage. Palm oil has too high a melting point to give the right appearance on cold served foods or snacks (Pantzaris TP, 1999). Palm oil and its fractions are accepted as frying oils for food products such as snack chips, crackers, cookies, pastries, doughnuts, fries and instant noodles. Frying, being a thermal process, results in rapid deterioration of oil (Wai Lin S, 2002).

***Soybean or Rapeseed oil*:** They have high IV and low level of SFAs. They are fully fluid even at low ambient temperatures. These liquid oils have a poor oxidative stability due to the presence of linolenic acid (6-10%). Linolenic acid oxidizes 100 times faster than oleic acid (Nawar WW, 1993). Therefore, rapeseed oil is blended with other more stable oils or is partially hydrogenated. Both soybean and rapeseed oils are often used where storage of the fried food is not necessary. Use of soybean oil for frying showed poor oxidative stability than palm oil, canola oil sunflower oil and palm olein (Machado ER et al, 2007; Abdulkarim SM et al, 2008).

***Groundnut oil*:** It was considered to be a premium frying oil. Its popularity has declined due to its cost and the worry of public regarding peanut allergy and aflatoxin problems (Pattee HE, 2005). It is sufficiently fluid at ambient temperature. But in cold winter weather, it might solidify in pipes and drums. The low IV and near zero level of linolenic acid makes it an admirable oil. The most unsaturated component is linoleic acid which ranges from 15-43%. It has high (~ 46.7%) oleic acid content. Groundnut oil is susceptible to oxidation. However, absence of linolenic acid in groundnut oil provides it with greater oxidative stability compared to other specialty vegetable oils (Podmore J, 2002). Good acceptability of products fried in GNO makes it popular in western region of India (Gupta A and Sheth M, 2011).

***Rice bran oil*:** It is increasingly popular as frying oil due to its high smoke point and stability. High oryzanol Rice Bran Oil (RBO) and refined bleached and deodorized RBO used for french fried potatoes showed an enhancement in stability with increasing oryzanol content. RBO contains sterol esters called γ-oryzanol, which are claimed to have several health benefits. It is also rich in sterol γ-5 avenosterol–a sterol having antioxidant action at frying temperatures. RBO contain highest tocopherol content (1800ppm) than palmolein (840ppm) and sesame oil (604ppm) (Archana U and Premakumari S, 2005). Unrefined RBO contains 2-20% FFA, depending on the quality of bran. Because of its high FFA and color, it is difficult to refine RBO without reducing the amount of oryzanol (Abidi SL and Rennick KA, 2003).

Study by Valsalan A, Siddhu A and Sundararaj P in 2004 reported, when various products were fried RBO underwent less oxidative deterioration as compared to GNO.

***Olive oil*:** Olive oil is considered to be a premium frying oil, having low concentration of linoleic and linolenic acids and low levels of SFAs. Long shelf life of olive oil is also due to combination of various phenolic antioxidants inherent in olive oil. It is very flavor stable oil because of high oleic acid content (~ 80%). Frying performance of olive oil is linked to its relatively low melting point that which makes it easy to store at low temperatures. It drains from the fried food readily with no danger of solidification of frying oil leading to excess fat on fried foods (Cicerale S et al, 2009).

***Sesame seed oil*:** It is a specialist commodity. It has approximately equal amount of both oleic and linoleic acids and very low linolenic acid content. It contains powerful antioxidants viz., 800 mg/kg of tocopherol as mainly γ-tocopherol. The compounds sesamol, sesamin and sesamol all give antioxidant properties. It has a high potential for heat stability, but it is considered as an allergen (Hwang LS, 2005). Study by Archana U and Premakumari S (2005) stated that sesame oil: palmolein blend (70:30) was more stable than other blends ricebran oil: sesame oil, ricebran oil: palmolein when stored for 3 months. However, apparent changes were observed in all the blends after potato chips frying.

***Cottonseed oil*:** It contains moderately high amount of SFAs namely 21-26% palmitic, together with up to 4% of longer chain saturated acids. It contains oleic and linoleic acids at levels of 17 and 56% respectively; linolenic acid is less than 1%.It is more stable compared to other liquid oils and could replace lard as the preferred fat for baking and frying (O'Brien RD et al, 2005).

***Corn oil*:** It is considered to be superior frying oil when compared with canola and soybean oils. High sterol content could impart a lower viscosity and thus favor better drainage from the fried food. Corn oil's desirable properties include its mild nutty flavor, high levels of unsaturated fatty acids, low levels of saturated fatty acids, very low levels of linolenic acid, and stability during frying (Moreau RA, 2005).

***Corn, Partially hydrogenated soybean, Sunflower oils*:** These oils are used for frying snack food and for french fries. New developments in trans-free frying oils, rich in oleic acid and low in PUFA and SFA are producing oils with good stability (Cuesta C, Romero A and Sanchez-Muniz FJ, 2001; Barrera-Arellano D, Ruiz-Mendez MV and Velasco J, 2002).

2.10 Regulation of frying fats and oils in various nations

Oils used for frying have to be discarded after certain duration of use because of the harmful effects of the degradation products forming and accumulating in the oil. *Ab initio*, taste evaluation of the food products was considered the most important factor in the quality measurement. However, taste of the food product is not a function of the quality of the frying oil alone but of many other factors also. Moreover, the taste evaluation performed is unreliable for routine quality control testing because of its subjective nature. Thus there is a need for quantitative methods to evaluate the oil degradation in various oils.

In 1973, the German Society for Fat Research made the first attempt to define what "deteriorated fat" is. Definition given by German Society is described it as: "*a used frying fat is deteriorated if, without doubt, odor and taste are unacceptable; the concentration of petroleum ether insoluble oxidized fatty acids is 0.7% or higher and the smoke point is lower than 170°C; or if the concentration of petroleum ether insoluble oxidized fatty acids is 1% or higher*" (Fritsch CW, 1981).

Firestone D (1993) presented an overview of the laws, regulations, recommendations, and guidelines followed by a number of nations are listed below:

Belgium

In 1988, Belgium implemented laws forbidding the use of deteriorated frying oils. According to the law, frying oils should be discarded if any of the following criteria is not satisfied:

a) Frying fats should not be heated to 180°C.
b) Free fatty acid content should not be more than 2.5% by mass.
c) Dimeric and polymeric triglycerides should not be more than 10% by mass.
d) Polar compounds content should not be more than 25% by mass.
e) Viscosity should not be greater than 37 mPa-s at 50°C for frying fats and 27 mPa-s at 50°C for frying oils.
f) Smoke point should be above 170°C.

The Netherlands

The Netherlands follows the practice of regular inspection against the use of deteriorated frying fats and oils. According to the practice, frying fat must be discarded if any of the following conditions are not satisfied:

a) The oil must be satisfactory in the organoleptic evaluations by food inspectors.

b) The acid value should not exceed 4.5.

c) The polymeric triglycerides should not exceed 16% by mass.

France

In 1986, France regulation specifies that the fats and oils containing more than 25% by mass of polar compounds are deteriorated frying fats and oils therefore they are unfit for human consumption.

Spain

According to the Spain regulation 1989, frying fat should be discarded if any of the following conditions are not satisfied:

a) Frying fats and oils must be organoleptically acceptable.

b) The polar compounds should not exceed 25 % by mass, as determined by the IUPAC method #2.507.

c) Frying fats must not alter the quality of fried food.

d) Frying fat must not be sold for subsequent use in preparing other food products after it has been used in frying operations.

Austria

According to the recommendations given by Austria in 1990, frying oils should be discarded if any of the following conditions are not satisfied:

a) Frying fats should be organoleptically acceptable.

b) Frying fats should be acceptable in appearance (dark color, foaming) or should not contain high levels of carbonaceous residue.

c) Acid value should not be greater than 2.5.

d) Smoke point should be under 170°C.

e) Polar compounds should not be more than 27% by mass.

f) Oxidized fatty acids insoluble in petroleum ether above 1%.

g) Frying fat should not be heated above 180°C.

Germany

The definition of deteriorated frying fats and oils published by the German Society for Fat Research, following their two symposia in 1973 and 1979 were accepted as recommendations to prevent the use of deteriorated frying fats in Germany. Even though there is no specific law or regulation in Germany in this regard, it is noteworthy that these recommendations were established after numerous reports of gastrointestinal distress (Firestone D, Stier RF and Blumenthal MM, 1991). Based on recommendations, the German health authorities succeeded in bringing some cases to the court, resulting in a considerable improvement in the average quality of frying oils in Germany (Billek G, Guhr G, and Waibel J, 1978).

Finland

Finland follows general regulations for monitoring the use of degraded frying oil. Frying oils are considered harmful if any of the following conditions are not satisfied:

a) Oils should be organoleptically acceptable.
b) Fritest should not be greater than 2.
c) Acid value should not be greater than 2.
d) Smoke point should be below 180°C.
e) Decrease in iodine value compared with that of the unused oil should not be greater than 16 (Firestone D, Stier RF and Blumenthal MM, 1991).

The U.S.

The Food and Drug Administration (FDA) of the U.S. has not any specific laws or regulations against the use of deteriorated frying oils. However, certain guidelines for the use and discarding of frying oils in processing plants producing fried meat products are followed by the U.S. Department of

Agriculture (USDA). During Manufacturing Processes Inspection (MPI) Regulations published by the USDA is given below for meat products.

a) Length of time fats and oils may be used for deep-fat frying varies with temperature, quantity of new fat added daily, and fat treatment during use.
b) Suitability of these fats for further use can be determined from degree of foaming during use or from color, odor, and flavor. Excessive foaming, darkened color, and objectionable odor or flavor are evidence of unsuitability and require fat rejection.
c) Fat or oil should be discarded when it foams over the vessel's side during cooking, or when its color becomes almost black as viewed through a colorless glass container.
d) Serviceable life of fat can be extended by holding frying temperature below 400°F (204°C), daily replacing one third or more, filtering as needed, and cleaning the system at least weekly. Adding an antifoam agent (methyl-polysiloxane) to new fat is helpful to delay the degradation process.

Canada

Canadian 'Food and Drugs Act and Regulations' deals with the fats and oils. It covers only the specifications for the initial quality of the frying fats and oils only. No existing law or regulation in Canada against the use of deteriorated frying fats (FDAR, 2012).

Other Nations

Scandinavian countries had no specific laws and regulations for frying fats and oils, only certain general regulations are enforced. Norway and Denmark follow the methods of organoleptic evaluations, acid value, color, smoke point, free fatty acids, peroxide value, etc. to determine the quality of frying oils (Firestone D, Stier RF and Blumenthal MM, 1991).

Swedish National Food Administration has published guidelines for deep fat frying listed below:

a) Change oil before it starts smoking or foaming.
b) Strain the fat for at least once a day.
c) Frying temperature should be 160-180^{0}C.
d) Use that are specially intended for frying.
e) Avoid salting or seasoning the fried food over the fryer.
f) Lower the temperature when not frying and protect from light.
g) Use separate fryers for plant based and animal based foods.

Sweden accepts organoleptic evaluation, Fritest, peroxide value, free fatty acids, foam formation, etc. to determine the quality of degrading frying oil.

Israel has no specific regulations against the use of deteriorated frying fats. However, guidelines by the Swedish National Food Administration are followed by the inspectors of the Israeli Food Control Administration.

Japan has no formal laws and regulations, but they have guidelines to discard the fat when the smoke point is below 170°C, acid value is greater than 2.5, or carbonyl value is more than 50.

Switzerland also has no specific laws and regulations for frying fats. However, Fritest is commonly used by the food inspectors to check the quality of frying oils on routine inspections.

2.11 Food safety status in Indian institutes and catering outlets

Rapid industrialization and changing life styles, have led to the development of large scale catering services, which prepare and distribute food to the public. There has been a marked increase in the consumption of food outside home. Greater numbers of people eat meals prepared in the restaurants, canteens, fast food outlets and street foods.

Nowadays popularity of commercially ready-made foods is widespread all over the world and deep-fried products are most admired by consumers among them (Totani N, Ohno C and Yamaguchi A, 2006). Oil deterioration during deep frying may pose hazards due to reactions such as oxidation, polymerization, and hydrolysis. These reactions results in formation of harmful components such as *trans* fatty acids, highly oxidized or polymerized constituents of fatty acids and acrylamide.

Safety of food is an inherent component of food quality. Food safety implies absence of biological contaminants, adulterants, naturally occurring toxins or any other substance beyond safety limits and that make injurious to health on an acute or chronic basis. Food quality can be considered as a complex characteristic of food that determines its value or acceptability to the consumers (CAC/GL21-2003). In addition, safety of oils used for deep-frying is a vital criterion in the selection of frying fats and oils for the catering industry, unlike in the home where the frying fats are normally used once or twice and then discarded (Gertz C, Klostermann S and Kochhar SP, 2000).

Oxidized oil causes deterioration in taste, flavor, odor, color, texture, and appearance, and a decrease in the nutritional value of the fried foods. Use of such oils/consumption of such foods can induce food poisoning. Thus this indicates that there is a direct relationship between the quality of the food being produced and the oil in which it is being fried (Gotoh N and Wada S, 2006).

Application of Hazard Analysis Critical Control Point (HACCP) and training to personnel on safe frying practices showed an improved safety when sunflower oil was used for frying process (Soriano JM, Molto JC and Manes J, 2002). Another study on HACCP of frying ensures production of safe potato chips and french fries by controlling the critical limits so that potential hazards can be controlled (Vorria E, Giannou V and Tzia C, 2004). From food safety perspective such reactions must be suppressed. So far researches have undertaken to determine the time when frying oils reach their maximum safe levels of deterioration but no satisfactory and easy method of sensing the frying oil quality has been developed.

The protection of human health comprises an objective of fundamental importance internationally and is governed by Codex Alimentarius. HACCP approach on food safety focuses on the critical control points (CCPs) of food processing and is considered to be the most effective method to maximize product safety. It is a cost effective system and reduces the risk of manufacturing and selling unsafe products. Additionally, it is a highly specialized system for food safety which necessitates an analytical study to determine microbiological, chemical and physical risks.

Sheth M, Diwedi R and Bhatnagar G (2005) reported that dieticians of Baroda hospital were lacked in basic knowledge on preventive issues like HACCP, knowledge on food borne illness and their causative agents. High microbial counts above 10^5 CFU/gm/ml from the swabs of food contact surfaces in a hospital kitchen of Vadodara.

Epidemiological survey of E.coli O157 in different regions of India showed 30 (0.5%) human samples were positive for E.coli O157 out of 17,093 isolates cultured from various samples. High percent of E.coli O157 were isolated from meat (0.9%), milk and milk products (1.8%), seafood (8.4%) and water (1.6%) (Sehgal R, Kumar Y and Kumar S, 2007).

Dishwater and dish swabs samples of street vendors of Vadodara were found positive for Salmonella (80%) and (20%), E.coli (60%) and (40%) respectively (Sheth M and Gurudasani R, 2004).

Study by Mudey AB et al (2010) on health status and personal hygiene among food handlers at Wardha district of Maharashtra reported that the health status and the level of personal hygiene of the food handlers in the eating establishments were unsatisfactory. The cooks and suppliers who handled food were not maintaining a satisfactory personal hygiene, thereby increasing the risk of food contamination considerably.

Keeping in view of the above mentioned literature the present study was undertaken with the objectives summarized in Scope of Investigation chapter.

CHAPTER 1

INTROTDUCTION

Humankind has faced major shifts in dietary and physical activity patterns since paleolithic man evolved on Earth. Emergence of agriculture, modernization and urbanization has played a pivotal role in bringing about this change. Decades of research in the developed world have shown that much of the burden of chronic diseases is attributable to environmental and lifestyle factors, including dietary shifts and decreased physical activity. Variation in the risk of non-communicable diseases between high income countries and changing trends over time within the developing countries also indicates that the factors determining their incidences must be modifiable (Tullao TS, 2002). The World Health Organization (WHO) predicts that deaths due to circulatory system diseases are projected to double between 1985 and 2015. Increased intake of energy dense foods, along with lifestyle changes in the developing world has increased the focus on diseases of aging (Vaz M et al, 2007; Drewnowski A and Darmon N, 2005). Foreign distribution channels bring foreign diets, i.e. processed foods rich in sugars and fats and in general energy dense food (Shetty P and Schidhuber J, 2005). Additionally, production and easy availability of such foods has led to its increased consumption.

Fueled by urbanization and the advent of the global economy, these changes in eating patterns are the most rapid and dramatic in the course of human history. The term “Coca-colonization,” a reference to the ubiquitous presence of Coca-Cola, Pepsi, and McDonald’s, describes a world that is moving toward a common diet, one accompanied by the more sedentary lifestyles associated with increased risk of chronic disease (Zimmet P, 2000).

"Nutrition transition", the consumption of foods high in fats and sweeteners is increasing throughout the developing world, while the share of cereals is declining; intake of fruits and vegetables remains inadequate. The dietary transitions taking place are deeply rooted in the processes of globalization (Hawkes C, 2006). Globalization is associated with changing incomes and lifestyles. The concept of the nutrition transition focuses on large shifts in diet and activity patterns, especially their structure and overall composition. These changes are reflected in nutritional outcomes, such as changes in average stature and body composition.

Women who report a higher standard of living, who live in households where at least one member is educated beyond high school, who work in non manual occupations, or who watch television more than once a week are more likely to be overweight or obese. These factors are all inversely related with low BMI. In common with other studies in developing countries that are in the early stage of nutrition transition, Indian women in the highest socioeconomic groups are more likely to be overweight or obese, whereas nearly half of poor women are underweight (Singh RB et al, 1999; Dhurandhar NV and Kulkarni PR, 1992). According to analysis on morbidity trends, developing countries like India, Brazil and China are in the rapid transition phase because of large increase in non-communicable diseases.

India has been called the land of ***Annapurna***, is a vast and varied subcontinent, with 2.4 per cent of its global landmass supporting over one-sixth of the world's population (Ramachandran P, 2008). In a recent report by United States Department of Agriculture (USDA), India used 1,000 and 1,440 thousand metric tons of cottonseed and groundnut oil respectively for domestic consumption (USDA, 2010). Report by Nutrition Foundation of India (2008), reveals high fat consumption in prosperous urbanized states like Gujarat, Haryana, and Punjab. However, states like Orissa, Chattisgarh and Assam consume lesser fat (Ramachandran P, 2008). National sample survey organization, Government of India, reported that population of Gujarat consume 25kg/capita of oil every year, while the national average is only 11kg/capita. This epitomizes a clear picture of Gujarati population consuming the highest edible oil in our country (NSS, 2007). However, due to increasing awareness of consequences of consumption of energy dense foods, there is a need to document the source of energy especially with respect to edible oil.

Frequent/high oil or fried food intake is one of the reasons for increased prevalence of obesity, diabetes and CHDs all over the world (Weisburger JH, 2000; Mozaffarian D and Willett WC, 2007). Increased prevalence of abdominal obesity, hypercholesterolemia and T2DM (Type 2 Diabetes Mellitus) and low levels of HDL-cholesterol is also reported in Indian population (Misra A et al, 2001; Ghafoorunissa G, 2008). According to analysis on morbidity trends, developing countries like India, Brazil and China are in the rapid transition phase because of large increase in non-communicable diseases (WHO, 2008).

Use of Groundnut and Cottonseed oil for cooking various foods is very popular in western region of India especially Gujarat.

A major portion of vegetable oils produced in our country is utilized for frying food. Frying uses fats and oils as a heat transfer medium, where a crust is formed which seals in the water keeping the centre moist and reducing fat uptake. Several factors such as prolonged heating, high temperatures ($150\text{-}200^0$ C), oxygen, moisture content, presence of light, and impurities are known to cause hydrolysis, oxidation and polymerization of fats that may result in darker fat, strong flavors, lower smoke point, foaming and viscosity (Singh S and Tyagi VK, 2001; Aladedunye FA and Przybylski R, 2009; Dobarganes C, Márquez-Ruiz G and Velasco J, 2000; Saguy IS and Pinthus EJ, 1995).

Amongst the various cooking methods, deep frying is popularly used in India for preparing snacks and savories (Gupta A and Sheth M, 2011). Normally deep fat frying produces a product with desirable sensory characteristics, including fried food flavor partly derived from the formation of 2, 4-decadienal during thermal oxidation of linoleic acid (Warner K, Orr P, and

Glynn M, 1997). Another change commonly encountered during frying is development of golden brown color as the result of maillard reaction which depends on the content of reducing sugars and amino acids or proteins at the surface, temperature and time of frying. Crispness, which is also a desirable quality of fried foods can used as a quality indicator of freshness (Scanlon MG et al, 1994; Warner K, 2004). In addition, German Society for Fat Research has recommended that frying research should accompany sensory evaluation of fried product because formation of different decomposed products may cause alteration in the nutritional quality of oil and sensory quality of fried product as well (DGF, 2000).

The popularity of food prepared using repeatedly heated oils persists despite public concern about fat, cholesterol and the knowledge that fat intake should be in moderations and of good quality. Deteriorated oils are not only insidious cause of cancers, hypertension and coronary heart diseases but also result in foods with poor texture, flavor and shelf stability (Singh S and Tyagi VK, 2001; Soriguer F et al, 2003; Tsai WC et al, 2004; Goyal N and Sundararaj P, 2009).

Thermo oxidative stability of various oils is extensively studied by several researchers (Houhoula DP, Oreopoulou V and Tzia C, 2002; Warner K and Gupta M, 2003). However, most of the studies have been carried out with intermittent time periods of 80-90 h, and little attention is given to researches where the intermittent frying time matches the duration used at household and restaurants level.

Access to safe food has been man's main endeavor in order to live a healthy life. Safe food may be defined as, "a product which contains no physical, chemical or microbiological organisms or by products if consumed by man will result in illness, injury or death-an unacceptable consumer health risk" (Stier FR, 2000).

Rapid industrialization and change in life styles of people has resulted in marked increase in the consumption of food outside the house. Large numbers of eating establishments such as restaurants, fast food centers, dhabas, street food stalls, etc have mushroomed in cities of India, which are manned by different categories of workers (Sukul S and Sheth M, 2009). These eating places are frequented by both middle and high-income families with their children. Today eating out has become an important social activity, both at personal and professional levels due to changing dietary and lifestyle practices (Goyal N and Sundararaj P, 2009). Unhygienic preparation of food in such places provides ample opportunities for contamination, growth, or survival of food borne pathogens that may lead to diseases commonly referred as food borne illness (Gurudasani R and Sheth M, 2009).

According to Mazumdar S (1992) in catering establishments 40% of the food borne illness is caused by mishandling of food and cross contamination. The importance of safe food for health and development has been recognized and addressed in many international fores as well. Safe food is one of the three essentials for maintenance of life and health.

Apart from the microbial safety of foods, chemical changes in food during processing needs to be looked upon for their nutritional safety. Agreements in the form of legislation must be put in place in order to ensure that safe and healthy food reaches to consumers.

Because of unavailability of frying regulations in India, cooks in restaurants refry the same oil a number of times. Therefore frying regulations need to be established in India and monitored strictly which may help in reducing the rising trend of non-communicable diseases (NCDs) in India. Furthermore, it is necessary to elicit data on food safety practices performed at various food outlets in India to reduce the prevalence of food borne illnesses especially in relation to their hygiene and frying practices.

Thus present study entitled "Occurrence of chemical and sensory changes during intermittent frying of french fries and bhajias in Groundnut and Cottonseed oil and studying the association between the fried food intake by the Gujarati housewives and Non-communicable diseases" was undertaken in five phases:

PHASE I: Fried food intake, knowledge on fats and oils and frying practices of the Gujarati housewives of urban Vadodara and its association with the prevalence of NCDs**.**

PHASE II: Sensory qualities of french fries and bhajias fried in cottonseed oil (CSO) and groundnut oil (GNO) during intermittent frying.

PHASE III: Chemical changes due to thermal degradation of intermittently deep fried cottonseed oil (CSO) and groundnut oil (GNO) as a result of french fries and bhajias frying.

PHASE IV: Case study on prevailing food safety and frying practices in Jan aahar- A Government run food outlet at Vadodara railway station.

PHASE V**:** Development of Nutrition Health Education (NHE) material in two languages on intake of edible oil, types, and on choices of oils for healthy living and problems during frying of edible oil and its storage.

The fried food intake by Gujarati households was collected using food frequency questionnaire; knowledge on edible oil intake and frying practices was collected with the help of semi-structured questionnaire. The sensory quality assessment of intermittently fried french fries and bhajias was done by 9-point hedonic scale (Joshi VK, 2006). Determination of chemical quality of intermittently fried cottonseed oil (CSO) and groundnut oil (GNO) was done by standard AOAC, 1995; AOCS, 1998; AOCS, 1974; Lab manual 2 (7.0) GOI, 2005 and information on food safety and frying practices of Jan aahar kitchen staff was collected using a semi structured questionnaire.

The results of phase 1 showed that deep and shallow fried products prepared at home were consumed by 5% and 43% of Gujarati households on daily basis respectively. Maximum (58.8%) housewives were obese and prevalence of other co-morbidities such as hypertension and diabetes was 16% and 8% respectively. Significant association was found between obesity and diabetes; shallow fried food consumption and prevalence of diabetes. Many families reported daily use of saturated fats such as *vanaspati* (26%), ghee (100%) and butter (76%). Approximately 60% housewives did not know about the recommended daily intake allowances of oil. Fewer house wives had knowledge on *trans* fats and oil blends.

In phase 2, french fries and bhajias fried intermittently at 0, 6, 11, 16 and 21 h in CSO and GNO were evaluated for their sensory qualities. French fries fried in CSO were inferior at 21 h of intermittent frying than GNO fried fries. Bhajias showed no significant change during and at the end of 21 h intermittent frying in both the oils. As per hedonic scale both french fries and bhajias fried in two oils were acceptable up to 21 h of intermittent frying. Bhajias and french fries fried in GNO showed higher oil uptake than CSO.

Phase 3 was designed to study the occurrence of chemical changes in GNO and CSO used for frying french fries and bhajias at intermittent (0, 5, 10, 15, 20, and 25 h) frying durations. A significant ($p<0.001$) rise in oxidative parameters (PV, p-AV and TV) was observed in both the oils at 25 h of intermittent frying of french fries and bhajias. Decrease in iodine value of CSO was significant ($p<0.01$) during french fries and bhajias frying. Total polar components of CSO and GNO showed 83.8% and 89.4% increase during french fries frying. A higher increase (257.5% in CSO and 142.9% in GNO) in polar components of bhajias fried oils was observed. French fries frying showed significant decrease ($p<0.01$) in linoleic/palmitic acid ratio in CSO (25%) and GNO (33.8%). No significant change was seen in linoleic/palmitic acid ratio of both the oils during bhajias frying. CSO showed less stability in terms of overall chemical quality during 25 h of intermittent frying as compared to GNO.

Results of phase 4 revealed that knowledge on food hygiene of Jan aahar staff was 75% whereas nutrition and health knowledge was only 40.7%. 100% scores were obtained by most of the staff on personal hygiene. Lack in infrastructural facilities was observed. Cooks had good frying knowledge and practice discarding/use for sautéing of fried oil at the end of each day.

Thus it can be concluded that frequent intake of shallow fried food by Gujarati housewives is a contributing factor for occurrence of diabetes. There is lack of knowledge amongst them on quantity and quality of edible oil intake. Both french fries and bhajias were acceptable up to 21 h of intermittent frying for most of the sensory attributes. However, the chemical quality of both the oils deteriorated up to 25 h of intermittent frying. Between the two oils CSO was more unstable than GNO especially in terms of p-anisidine value, total polar components and linoleic/palmitic acid ratio. The case study of Jan aahar showed good knowledge regarding food safety and frying practices of kitchen staff.