CHAPTER 6
SUMMARY AND CONCLUSIONS

Over the past few years there has been increasing prevalence of obesity in India. According to a study India is the third most obese country in universal hazard list of top 10 countries with highest obese population. Simultaneously FOS is also gaining acceptance in large number of product and process development. The technological functionality of FOS as a fat and sugar replacer making some of the products low in calorie and fat can go a long way in providing healthy food choices to health conscious individuals. FOS is dietary fiber which is recently recognized for its health potential. By consuming this non-digestible ingredient, FOS allows for growth of beneficial bio-cultures in the gut after reaching the colon unaffected by the digestion process Adding on to human relevance FOS is thus a promising supplement in effecting obesity outcomes. Hence, this study was designed to study

"Sensory evaluation of fructooligosaccharide (FOS) added popular recipes of India and its role in modulating anthropometric indices, gut flora and lipopolysaccharide (LPS) in obese young adults of urban Vadodara".

The study was undertaken in the following four phases:

Phase I Development and Standardisation of FOS incorporated popular recipes of India and studying their various organoleptic attributes and overall acceptability.

Phase II Situational analysis: mapping the prevalence of various grades of obesity in banks employees of Urban Vadodara (A cross-sectional design).

Phase III Comparison of grade-I obese subjects with non-obese subjects in terms of anthropometry profile, medical history, family history of diseases, defecation profile, hunger and satiety, psychological

depression status, dependency on habits, dietary intakes, biophysical profile, lipemic profile, plasma LPS levels and gut microbiota (*LAB, bifidobacteria, bacteroides and clostridium*) and understanding the correlations between various parameters.

Phase IV Effect of fructooligosaccharide (FOS) supplementation on anthropometry, defecation, hunger and satiety, depression, dietary, lipemic parameters, LPS and gut microflora in obese grade-I adults.

The results and major highlights of all the phases of the study are summarized below:

6.1: PHASE I

This section of the study was carried out to develop FOS incorporated food products *viz. lilva kachori, vegetable parantha, rawa idli* and *chocolate cake* by adding and substituting varying level of FOS. Four products were selected on the basis of their cooking method namely deep frying, shallow frying, steaming and baking. Filling material of *lilva kachori and vegetable parantha* were added with FOS at three *viz*. 5g, 10g, and 15g and at two levels *viz* 10g and 15g respectively and in *rawa idli* base material (semolina) was added with FOS at three levels *viz* 10g, 15g, and 20g. In *chocolate cake* butter and sugar were substituted with FOS at three levels *viz* 10g, 20g, and 30g. 25 semi trained panel of judges evaluated these food products using ten points Numerical scoring test. All the products were studied for their sensory characteristics in triplicates.

Salient Features of Phase I

6.1.1 Organoleptic properties of FOS added/substituted food products

- *Lilva kachori* was well accepted upto 5g of FOS addition without affecting sensory attributes. At higher levels of FOS incorporation, a

significant gradual decrease in all the sensory attributes was exhibited, where color and appearance, texture and aftertaste were greatly affected.

- FOS can be incorporated to *vegetable paratha* upto 15g level without affecting organoleptic qualities.
- 15g addition of FOS added *rawa idli* was highly acceptable in terms of color and appearance, mouth feel, texture, taste, after taste and the overall acceptability. As the level of FOS incorporation increased beyond 15 g all sensory scores decreased.
- No significant difference was evident in any of the organoleptic attributes of *chocolate cake* at all the levels of FOS substitution (10, 20 and 30g) when compared to standard. Substitution of fat and sugar with 20g FOS was most acceptable alternative.

From this phase it can be concluded that FOS can be incorporated in all the four food products studied. However, rawa idli and chocolate cake remained the most acceptable products even at the higher (20g) level of FOS addition/substitution. Lilva kachori and vegetable parantha were acceptable upto 5g to 10g of FOS addition.

6.2 PHASE II

The present phase was planned to map the prevalence of various grades of obesity in banks employees of urban Vadodara (A cross-sectional design). For achieving the desired objectives, a total of 10 different banks from different areas of Vadodara city were conveniently selected based on the permission obtained from the administration department to organize the health screening camp. A total of five hundred and ninety five (595) bank employees irrespective of age and gender were screened for their anthropometric measurements, body fat percentage, basal metabolic rate and blood pressure.

Salient Features of Phase II

6.2.1 Distribution of subjects according to gender and age

- Out of five hundred and ninety five subjects screened, 75.79% were males and 24.20% were females.
- Out of these 70.50% of the males and 63.19% females were in the age group of 26-35 years respectively.

6.2.2 Classification of subjects according to the various categories of BMI

- Only 30.3 percent of males and 38.88 percent of female had normal BMI.
- Overall 7.2% of bank employees were underweight.
- A total of 7.05 percent subjects fell into obesity-grade II category. A total 37.25 percent male and 22.91 percent female were in obesity-grade I category.
- The prevalence of obesity was observed to be 40.83% (BMI ≥25) and 19.29% for overweight (BMI 23–24.9).

6.2.3 Prevalence of abdominal obesity and central obesity in bank Employees

- According to cut offs for waist circumference and waist hip ratio given by WHO 43.45% of males and 38.19% of female subjects showed the presence of abdominal obesity.
- 44.12% males and 30.55% females were at risk of developing central obesity.

6.2.4 Distribution of subjects according to levels of body fat percent

- According to body fat percent levels 61.41% males and 52.7% of females had ≥25% of fat mass and females had ≥32% of fat mass in their body respectively.
- Only 6.8 % of total subjects were fit according to body fat percent levels.

6.2.5 Prevalence of hypertension in the bank employees

- Approximately more than 46% of subjects were pre-hypertensive and 15% of subjects had moderate hypertension.
- Male were more hypertensive than females.

6.2.6 Anthropometric and biophysical profile of the subjects

- The mean BMI of the participants was 24.17±4.14.
- Mean waist circumference was 85.15 cm and mean hip circumference was 95.9 cm.
- Mean BP of the bank employees was approx. 127/77 mmHg.
- Male and females both had approx. 8-10 kg. weight when compared to standard weight.

From this phase it can be concluded that the prevalence of obesity and hypertension was high in the staff of the selected banks.

6.3 PHASE III

In this section of the study an attempt was made to study the difference between non-obese and obese individuals with regards to their anthropometry profile, medical history, family history of diseases, defecation profile, hunger and satiety, psychological depression status, dependency on habits, dietary intakes, biophysical profile, lipemic profile, LPS and gut microbiota (*LAB, bifidobacteria, bacteroides and clostridium*) and understand the correlations amongst these parameters. For achieving the desired objectives, a total of 200 subjects were enrolled (100 non-obese and 100 obese) and screened based on inclusion and exclusion criteria. Informed consent was obtained from them.

Salient Features of Phase III

6.3.1 Background information of obese and non-obese young adults

- More number of subjects belonged to non-obese category of younger age group than older age group.
- There were more males (162) than females (38) in both the categories with majority of subjects being Hindu.
- 95% of obese and 91% of non-obese subjects were at least graduates or had higher degree in education.
- Most subjects came from nuclear family and belonged to upper middle class.
- The monthly per capita income of majority of participants was greater than Rs 28,114 per month for both the obese and non-obese subjects.

6.3.2 Anthropometric profile of obese and non-obese young adults

- The mean BMI of obese subjects was 27.6 kg/m^2 and for non-obese it was 21 kg/m^2.
- Waist circumference and hip circumference were higher in obese subjects.
- Obese male subjects had ≥25% body fat and obese female subjects had ≥32% body fat.

6.3.3 Percent prevalence of abdominal obesity based on waist circumference and waist hip ratio in obese and non-obese young adults

- Prevalence of abdominal obesity was significantly high ($p<0.000$) in obese subjects (84%) compared to non-obese subjects (9%).
- Obese subjects were 53.08 times at a higher risk of developing abdominal obesity. Obese subjects also showed high prevalence of central obesity.

6.3.4 Percent prevalence of obesity in the subjects according to percent body Fat

- 100% obese female subjects had >32% body fat where as only 12.50% non-obese females had >32% body fat.
- 94.18% obese male subjects had greater than 25% of body fat.

6.3.5 Hypertension profile of obese and non-obese young adults

- Although 77% of obese and 64% of non-obese subjects was pre-hypertensives, their diastolic blood pressure was within the normal range in both obese and non-obese subjects.
- Systolic blood pressure crossed the normal limits of 120mmHg.
- Obese were 1.88 times at a higher risk of developing hypertension. A significant difference ($p<0.01$) was observed in systolic blood pressure of obese and non-obese females.
- Mean values for blood pressure were significantly ($p<0.01$) high in obese subjects (127.08/79.90) when compared to non-obese subjects (122.88/76.37).

6.3.6 Family history of disease and personal medical history of obese and non-obese young adults

- Family history of NCD's was more common in obese than non-obese subjects.
- Most of obese subjects had strong family history where only 15% of non-obese had strong family history.
- There was a significant association (χ^2 Value-26.61***) between family history of disease with BMI of the subjects.
- Subjects with severe family history of co-morbidities were at 5.13 times higher risk of developing obesity [OR-5.13; CI (2.69-9.77)].

6.3.7 Personal medical history of obese and non-obese young adults

- In study groups more non-obese subjects (52%) had gastrointestinal disorders like heartburn and acidity compared to obese subjects (29%).
- Medical history revealed that with regards to dental problems 74% of non-obese had cavities, dry mouth, bleeding/swollen gums and bad breathe whereas 61% obese subjects had such problems.
- Locomotor disorders like knee joint pain and back pain was more prevalent in obese subjects (51%) whereas less non-obese subjects (10%) reported similar kind of problems.

6.3.8 Defecation profile of obese and non-obese young adults

- There was a difference in defecation profile of non-obese and obese subjects.
- As per subjects perception 27% non-obese subjects and 38% obese subjects reported the presence of constipation.
- There was a non-significant association found between BMI and defecation profile of the subjects [χ^2 Value-2.99^{NS}; OR-1.84; CI (0.91-3.70)] but after administering the tool to know the detailed defecation profile of the subject results revealed that 26% of obese and 16% of non-obese had constipation.

6.3.9 Personal habit profile of obese and non-obese young adults

- Obese subjects consumed more alcohol (60%), cigarette (29%), tea (67%), and coffee (21%) compared to the non-obese subjects.
- Significant association was seen between BMI and intake of alcohol (χ^2-10.53**), cigarette (χ^2-4.04*) tea (χ^2-20.38***), and coffee (χ^2-6.78**).
- 63% of obese subjects were found in severe to extreme category of dependency on habits compared to 36% of non-obese subjects.

- No association [χ^2 Value-3.70^{NS}; OR-2.15; CI (0.97-4.73)] was observed between the BMI and dependency on habits.

6.3.10 Physical activity level of obese and non-obese young adults

- Almost equal percentage of non-obese and obese subjects belonged to sedentary and moderate level of physical activity.
- No significant association was observed between BMI and physical activity level of non-obese and obese subjects.

6.3.11 Psychological depression profile of obese and non-obese young adults

- 20% of non-obese subjects suffered from borderline clinical depression to severe depression as compared to 8% obese subjects.
- No significant association was observed between BMI and varying degree of depression.

6.3.12 Hunger and satiety pattern of obese and non-obese young adults

- No significant difference was observed in the mean hunger scores of non-obese and obese subjects.
- The intensity of hunger pattern was same in both the groups. However, the satiety was significantly delayed ($p<0.001$) in obese subjects at the specific meal time of breakfast, lunch, evening and dinner compared to non-obese subjects.
- The non-obese subjects consumed less quantity of food and had early satiety compared to obese individuals.

6.3.13 Frequency of consumption of food and dietary intakes of obese and non-obese young adults

- Consumption of fibrous fruits was reported more by non-obese subjects as compared to obese subjects.
- A significant higher intakes of all the macro nutrients in obese male as compared to non-obese male ($p<0.01$), whereas, energy and fat intake was significantly higher in obese females than non-obese female subjects ($p<0.05$).
- Obese males also had significantly higher total dietary fiber intakes as compared to non-obese males ($p<0.01$).
- Sodium intakes were also found to be significantly higher in both obese males and females than non-obese males and females.

6.3.14 Atherogenic profile of obese and non-obese young adults

- The mean serum cholesterol levels of obese was significantly higher than non-obese but both the groups were within the normal range.
- Mean serum TG levels of obese subject were 194.61 mg/dl which exceeded the normal values where in non-obese it was slightly higher.
- HDL cholesterol was at lower side in both the groups. Both the groups were at risk as the TC/HDL ratio was higher than 4.

6.3.15 Endotoxemia in obese and non-obese young adults

- Metabolic endotoxemia (as indicated by high LPS values) was more prominent in obese (47.06%) as compared to non-obese subjects (35.29%).
- A non significant association was found between BMI and endotoxemia.
- The mean value for LPS was found to be significantly high by 8.52 pg/ml in obese subjects as compared to non-obese subjects.

6.3.16 Gut profile of obese and non-obese young adults

- The fecal microbial load of non-obese and obese subjects revealed that the gut of the non-obese subjects was colonized more with the friendly

bacteria like *lactic acid bacteria* and *bifidobacteria* as compared to obese subjects.

- The gut of the obese subjects was colonized with higher counts of *bacteroides* and *clostridium* as compared to non-obese subjects which are potential pathogens.

6.3.17 Correlation amongst anthropometric parameters, blood pressure, defecation status and lifestyle factors in non-obese and obese subjects

- Age was positively corelated with anthropometric parameters and blood pressure.
- Weight, BMI, WC, WHR, percent body fat and diastolic BP were found to be significantly positively associated with family history of diseases.
- Defecation status was negatively associated with BMI, waist circumference and percent body fat which means as BMI, waist circumference and percent body fat increased constipation increased.
- A positive significant association was also seen amongst alcohol intake, cigarette smoking, tea and coffee intake and weight, BMI, WC and WHR. Subjects who were more dependent on personal habits had more weight and BMI as these were positively correlated with each other.

6.3.18 Correlation amongst anthropometric parameters and dietary intakes in non-obese and obese subjects

- All the anthropometric parameters were significantly positively associated with intake of macronutrients and total PUFA intake.
- Percent body fat positively correlated with energy and fat intake and total PUFA intake.
- Sodium intake was also found to be positively correlated with all the anthropometric parameters and percent body fat.

- Total dietary fiber was seen to be positively correlated with all anthropometric parameters. Total MUFA intake was positively correlated with waist circumference.

6.3.19 Correlation amongst anthropometric parameters, lifestyle factors, atherogenic profile, gut flora and endotoxemia in non-obese and obese subjects

- Age was significantly positively associated with total cholesterol, serum TG, VLDL, bacteriodes and LPS and negatively correlated with *Lactic acid bacteria*.
- A significant positive correlation was seen between weight and BMI with atherogenic profile, LPS and *Bacteriodes* and a negative corelation was seen with *Lactic acid bacteria*.
- Systolic blood pressure was negatively correlated with *Clostridium.* Family history of diseases was positively correlated with atherogenic profile, LPS and *Bacteriodes*.
- Defecation status was positively correlated with *Bifidobacteria* and Lactic acid *bacteria* while alcohol intake was negatively corelated with these.
- Physical activity level and depression status negatively correlated with *Bacteriodes*.
- Hunger scores negatively correlated with LPS and satiety scores negatively correlated with *Bifidobacteria* and *Clostridium*.

6.3.20 Correlation amongst dietary intake, atherogenic profile, gut flora and endotoxemia in non-obese and obese subjects

- Energy intake, CHO intake, fat intake, fatty acid intakes negatively associated with *Bifidobacteria*. *Clostridium* was negatively correlated with CHO, total MUFA and total saturates intake and *Lactic acid bacteria* was negatively correlate with fat intake.

- Bacteriodes was positively correlated with fat, protein, sodium and total PUFA intake. A positive correlation was found between total cholesterol, serum TG and VLDL with energy, protein and sodium intake.
- LPS is significantly positively associated with protein intake and total dietary fiber.

6.3.21 Relationship of BMI with direct and indirect determinants of obesity

- LPS, sodium intake, carbohydrates intake, tea intake, alcohol intake, family history of disease, protein intake, *LAB, bacteroides*, total PUFA intake, fat intake and energy intake were found to be the predictor of obesity to the accuracy of 53.1%.
- Factors that contributed to obesity ranked in the order of contribution were intake of fat (β=0.452) followed by intake of energy (β=0.344), *LAB* (β=0.312), *Bacteroides* (β=0.257), intake of sodium (β=0.243) and intake of tea (β=0.231) were found to be the significant contributors.

Present phase of the study concluded that there were statistically significant differences in obese and non-obese subjects with respect to gut microbiota, LPS, heredity, atherogenic indices, defecation, diet, hunger-satiety regulation, smoking and drinking alcohol. Obese were at higher risk of developing metabolic syndrome when compared to non-obese. In the perspective to this scenario, obesity needs to be addressed immediately. It can be achieved by modulating gut microbiota by means of prebiotics and probiotics, which may bring out positive changes in obesity status.

6.4 PHASE IV

The present phase of study was designed to observe the effect of FOS supplementation on obese individual for their anthropometric indices, blood pressure, defecation profile, hunger and satiety scores, depression status,

atherogenic profile, plasma LPS level and gut microbiota (*LAB, bifidobacteria, bacteroides and clostridium*).

For achieving the desired objectives, a total of 116 obese subjects were enrolled and randomly divided in two groups with the help of random tables i.e. experimental and placebo groups which received FOS (20 g) and dextrose (20 g) respectively for 90 days. Post intervention the sample size remained as 51 in experimental group and 32 in placebo group, after considering the dropouts due to various reasons.

Salient Features of Phase IV

6.4.1 Anthropometric profile of obese subjects before and after intervention with FOS

- Both the placebo and control group was statistically same before the intervention.
- Experimental group showed significant reduction in weight (1.44%) and BMI (1.32%) after intervention with FOS for 90 days.
- A significant reduction was also seen in waist circumference by 2.18%, WHR by 2.15% and percent body fat by 2.92%.

6.4.2 Blood pressure of obese subjects before and after intervention with FOS

- Both the placebo and experimental group was similar before the intervention.
- Systolic blood pressure values significantly reduced by 1.79% ($p<0.001$), where diastolic blood pressure values also reduced non-significantly in experimental group subjects after intervention.

6.4.3 *Defecation profile of obese subjects before and after intervention with FOS*

- Defecation profile of both the placebo and control group was statistically same before the intervention.

- As per subjects perception 88.24% subjects reported absence of constipation after intervention in experimental group.
- Frequency of passing the stool in a day increased significantly from one time to two-three times in a day and fecal output also increased significantly in experimental group subjects post intervention indicating better cleaning of stomach.
- Hardness and odor of stool reduced significantly ($p<0.001$) after intervention in experimental group subjects.
- Feeling after defecation significantly improved from bad to fine post intervention in experimental group.
- Degree of constipation reduced significantly ($p<0.001$) from moderate to absence of constipation after intervention in experimental group subjects.
- Overall defecation profile improved significantly however placebo group remained unaffected post intervention.

6.4.4 Hunger and satiety scores of obese subjects before and after Intervention with FOS

- A significant reduction in the appetite by 12.83% and 15.12% during lunch and dinner time respectively in experimental group subjects after intervention.
- Overall a non-significant increase in appetite in terms of the total mean hunger scores was found to be 0.75% and 3% in experimental and placebo group subjects respectively after intervention.
- A significant improvement was seen in achieving early satiety during most of the meal times.
- Highest reduction in satiety scores was observed at the lunch time by 8.94%, followed by dinner (8.23%) and breakfast (3.58%) in experimental group subjects.

6.4.5 Depression status of obese subjects before and after intervention with FOS

- A significant improvement was observed in mean depression scores in experimental (29.24%) as compared to placebo (1.36%) group subjects.
- Scores were in the reference range for both the groups' pre and post intervention.

6.4.6 Dietary intakes of obese subjects before and after intervention with FOS

- Consumption of FOS significantly reduced the mean dietary intakes of energy (8.58%), CHO (8.55%), protein (8.39%), and fat (10.42%) in experimental group subjects.
- Soluble dietary fibre and total dietary fibre intake were increased significantly in experimental group.

6.4.7 Atherogenic indices of obese subjects before and after intervention with FOS

- Both the groups were statistically similar before intervention.
- A reduction was seen in overall atherogenic profile where total cholesterol and serum triglycerides decreased significantly by 15.23% and 22% respectively in experimental group after supplementation.
- Low density lipoproteins and very low density lipoproteins were also reduced significantly by 16.02% and 21.99% in experimental group post supplementation.
- A significant reduction in TC, STG, and VLDL were also observed in placebo group post intervention but in minor extent. HDL remained unaffected in both the groups.

6.4.8 Endotoxemia in obese subjects before and after intervention with FOS

- LPS levels reduced non-significantly by 14.5% in placebo group and 4.03% in experimental group post intervention.
- There was no significant difference was found in the LPS levels of both the group before and after intervention.

6.4.9 ***Gut microflora counts in terms of Bifidobacteria, LAB, Bacteroides and Clostridium of obese subjects before and after intervention with FOS***

- Both the group was statistically similar with respect to their gut profile before intervention.
- FOS supplementation significantly colonizing the gut with the friendly bacteria like *Bifidobacterium* and *Lactobacillus* by 10.87% and 30.54% respectively.
- A significant reduction was observed in the counts of *Bacteroides* by 11.40 % ($p<0.001$) and non significant reduction in *Clostridium* counts by 1.95%.

From this phase of the study it can be concluded that FOS is able to counteract several metabolic alterations linked to obesity including defecation, hunger and satiety, depression, dietary, lipemic parameters and gut microflora in obese grade-I adults.

MAJOR CONCLUSIONS

- ❖ FOS can be incorporated in all the four food products studied. However, rawa idli and chocolate cake remained the most acceptable products even at the higher (20g) level of FOS addition/substitution followed by lilva kachori and vegetable parantha it can be added upto 5g to 10g.
- ❖ From this phase it can be concluded that the prevalence of obesity and hypertension was high in the staff of the selected banks.
- ❖ There were statistically significant differences in obese and non-obese subjects with respect to gut microbiota, LPS, heredity, atherogenic indices, defecation, diet, hunger-satiety regulation, smoking and drinking alcohol. Obese were at higher risk of developing metabolic syndrome when compared to non-obese. In the perspective to this

scenario, obesity needs to be addressed immediately. It can be achieved by modulating gut microbiota by means of prebiotics and probiotics, which may bring out positive changes in obesity status.

- Daily intake of FOS for a period 80-90 days proved to be successful strategy in reducing body weight and in altering the direct and indirect determinants of obesity influencing metabolism in terms of improving blood pressure, defecation profile, dietary intakes of macronutrients, hunger and satiety scores, depression status, lipemic parameters and positive shift towards healthy gut flora.

From above results the all three working hypothesis were not accepted.

- There were no similarities between fructooligosaccharide substituted/added food products with standard product in their organoleptic characteristics.
- There is a difference in grade-I obese subjects and non-obese subjects in terms of anthropometry profile, medical history, family history of diseases, defecation profile, hunger and satiety, psychological depression status, dependency on habits, dietary intakes, biophysical profile, atherogenic profile, endotoxemia and gut microbiota (*LAB, bifidobacteria, bacteroides and clostridium*) and no correlations existed between various parameters.
- 20 gram fructooligosaccharide (FOS) supplement has an effect on anthropometry profile, blood pressure, defecation profile, hunger and satiety, psychological depression, dietary intakes, lipemic parameters, plasma LPS level and gut microbiota (*LAB, bifidobacteria, bacteroides and clostridium*) in obese grade-I adults.