DEVELOPMENT AND CHARACTERIZATION OF '*SMURFIES*': A BLUE PEA FLOWER (*CLITORIA TERNATEA)* POWDER-ENRICHED EXTRUDED MILLET AND MILK PROTEIN-BASED BREAKFAST CEREAL

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By

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CERTIFICATE

This is to certify that the research work presented in this thesis has been carried out independently by Ms. Hetvi Salunke under the guidance of Dr. Kanchi Baria in pursuit of a Master's degree in Foods and Nutrition (Dietetics) and this is her original work.

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-Hetvi Salunke

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LIST OF ABBREVIATION

A.O.A.C	:	Association of Official Analytical Collaboration
AA	:	Ascorbic acid
ASLS	:	Accelerated Shelf-Life Study
ASLT	:	Accelerated Shelf-Life Testing
a_w	:	Water Activity
BCAA	:	Branched chain amino acids
Bd wt	:	Body Weight
BV	:	Biological Value
BW	:	Body Weight
CFU	:	Colony Forming Units
CHO	:	Carbohydrates
CSC	:	Composite Score Card
EAAs	:	Essential Amino Acids
FDA	:	Food and Drug Administration
FFA	:	Free Fatty Acids
FSSAI	:	Food Safety and Standards Authority of India
g	:	Gram/s
g/h	:	Gram Per Hour
g/kg/d	:	Gram/kilogram body weight/day
HTST	:	High Temperature, Short Time
HWP	:	Hydrolyzed Whey Protein
IFCT	:	Indian Food Composition Tables
INR	:	Indian Rupee
ISP	:	Isolated Soy Protein
K	:	Thousand
Kcal	:	Kilo Calories
Kg	:	Kilogram
KJ	:	Kilo Joules
LDPE	:	low-density polyethylene
MEq	:	Milliequivalent

MGP	:	Multigrain premix
min	:	Minute/s
Mm	:	Millimetres
MP	:	Milk Protein
MPC	:	Milk Protein Concentrate
MPI	:	Milk Protein Isolate
MPS	:	Muscle Protein Synthesis
NaCl	:	Sodium Chloride
NIN	:	National Institute of Nutrition
OAA	:	Overall acceptability
PRIM	:	Protein-Rich Ingredient Mixture
RDA	:	Recommended Dietary Allowance
RH	:	Relative Humidity
SD	:	Standard Deviation
SPI	:	Soy Protein Isolate
TBC	:	Total Bacterial Count
TPA	:	Texture Profile Analysis
TSE	:	Twin Screw Extruder
UK	:	United Kingdom
USA/US	:	United States of America
USD	:	United States Dollar/s
WPC	:	Whey Protein Concentrate
WPC-80	:	Whey Protein Concentrate-80
°C	:	Degree Celsius
9-PHS	:	9-Point Hedonic Scale
BMI	:	Body Mass Index
BPF	:	Blue Pea Flower
YP	:	Yellow Pea
w/w	:	Weight by weight
LDPE	:	low-density polyethylene
UTM	:	Universal Testing Machine
TPC	:	Total Plate Counts
OGTT	:	Oral Glucose Tolerance Test
GI	:	Glycaemic Index

ISO	:	International Organization for Standardization
WHO	:	World Health Organization
FAO	:	Food and Agriculture Organization
iAUC	:	Incremental area under the curve

ABSTRACT

ABSTRACT

Breakfast plays a pivotal role in maintaining nutritional adequacy, cognitive performance, and metabolic health. However, rapid urbanization and modern lifestyles have contributed to increased breakfast skipping, particularly among young adults and working individuals. The lack of time, coupled with a shift away from traditional food practices, has created a demand for functional, ready-to-eat breakfast options that are nutritionally balanced, convenient, and culturally relevant. The present study aimed to develop and characterize a novel extruded breakfast cereal, termed Smurfies, enriched with Blue Pea Flower (Clitoria ternatea) powder, millets (finger millet and kodo millet), and whey protein concentrate (WPC-80)—targeting improved antioxidant capacity, protein content, and glycemic response.

The study was structured in three distinct phases. In Phase I, a comprehensive market survey was conducted on 45 commercially available breakfast cereals from 12 brands. This assessment provided insights into ingredient trends, nutritional gaps, and consumer demand for millet- and protein-based cereals. Based on this, Smurfies were formulated by incorporating blue pea flower powder at three concentrations (0%, 5%, and 10%) into a blend of millets and whey protein. The extrusion process was carried out using a twin-screw extruder under controlled temperature and pressure to yield expanded cereal products.

Phase II focused on the nutritional, physicochemical, functional, and microbial evaluation of the extruded products. Proximate analysis revealed that increasing levels of blue pea flower led to a significant enhancement in protein (12.3% to 13.2%), fat, and ash content, with a marginal change in carbohydrate composition. The energy value remained consistent across samples (357–360 kcal/100g). Antioxidant activity, measured using the DPPH radical scavenging assay, increased progressively with higher blue pea flower concentrations, with the 10% BPF sample exhibiting the highest antioxidant potential (71.58%). Texture analysis indicated a favorable reduction in hardness and improved crispiness with BPF addition, enhancing palatability. Microbiological testing confirmed the safety and stability of all formulations over a 7-

week storage period, with water activity levels maintained below 0.7. Cost analysis demonstrated that the enriched product remained economically viable, with per-serving costs ranging from Rs. 30.10 to Rs. 39.04. Additionally, a glycemic index (GI) study involving healthy adult volunteers revealed that both 0% and 5% BPF Smurfies had low GI values (53 and 51, respectively), affirming their suitability for blood glucose regulation and diabetes-friendly diets.

In Phase III, Smurfies were incorporated into six breakfast recipes—parfait, smoothie, muffins, bread, granola, and bars—to assess their culinary adaptability and consumer acceptability. Each recipe was developed using all three Smurfies variants (0%, 5%, and 10% BPF) and evaluated by semi-trained panelists (n = 30–35) using a composite scorecard and 9-point hedonic scale. Sensory evaluation results indicated that products formulated with 5% BPF (Sample B) consistently scored the highest in terms of appearance, flavor, texture, mouthfeel, and overall acceptability. Parfait and granola preparations received the highest consumer preferences, followed by smoothies. Recipes with 10% BPF, while rich in antioxidant activity, exhibited a slightly bitter aftertaste that affected acceptability in items such as bars and bread. Consumer perception studies further revealed strong interest and willingness to adopt Smurfies-based products, with over 75% of respondents expressing positive views on its nutritional, environmental, and cultural value.

In conclusion, the development of Smurfies represents a successful integration of functional food science, traditional ingredients, and modern food processing. The product meets the growing demand for antioxidant-rich, protein-dense, low-GI breakfast cereals, while promoting the use of sustainable millets, milk-derived proteins, and botanical extracts like Clitoria ternatea. Smurfies offer a promising solution for addressing nutritional deficiencies, improving dietary habits, and supporting preventive health in diverse consumer groups. Future work may include clinical trials, large-scale production feasibility, and exploration of additional functional ingredients to further enhance the product's health benefits and market reach.

INTRODUCTION

CHAPTER 1

INTRODUCTION

Breakfast is often acknowledged as a crucial part of a healthy diet. Research has repeatedly demonstrated how it supports a better lifestyle overall, encourages better eating habits, and helps maintain a lower Body Mass Index (BMI) (Haldar et al., 2023). Breakfast consumption on a regular basis has also been linked to a number of physical and mental health advantages. For instance, it is favourably connected with better academic results and helps to increase cognitive performance, especially in children and adolescents (Mohiuddin, 2019).

Breakfast is an important source of both macro- and micronutrients from a dietary aspect. Regular breakfast eaters have a higher chance of meeting daily dietary requirements, especially for calcium, iron, vitamin C, dietary fiber, and folate (Gibney et al., 2018). Additionally, by controlling hunger signals, lowering daily calorie intake, and avoiding impulsive snacking or overeating, regular breakfast consumption helps with weight management (Dhurandhar et al, 2014).

Regular breakfast consumption is also strongly associated with cardiovascular health. Regular breakfast eaters are less likely to experience high blood cholesterol, hypertension, and other cardiovascular conditions (Takagi et al., 2019). These results highlight the wider significance of breakfast as a preventative strategy against chronic lifestyle diseases as well as a source of daily energy.

On the other hand, missing breakfast can negatively impact cognitive and metabolic health. According to recent studies, skipping breakfast is linked to higher levels of the recognized cardiovascular disease risk factor low-density lipoprotein cholesterol (LDL-C) in the blood (Yu et al., 2023). Furthermore, missing breakfast can throw off the body's circadian cycle, which can result in poor sleep, decreased insulin sensitivity, and decreased glucose absorption—all of which raise the risk of Type 2 Diabetes Mellitus (Shetty, 2023). The significance of frequent morning meals in preserving mental clarity and energy balance is further highlighted by Zhang et al. (2024), who claim that skipping breakfast can disrupt energy homeostasis and impair cognitive function.

Breakfast consumption evolves into a necessary habit that supports health rather than merely a regular routine. Promoting regular, balanced breakfast consumption is a strategic public health strategy that seeks to preserve metabolic health, enhance nutritional status, and prevent non-communicable diseases.

However, studies in India have revealed that a significant section of the populace either completely misses breakfast or eats meals that are nutritionally deficient, especially in critical elements like dietary fiber, iron, and other crucial micronutrients. Young individuals, working professionals, and school-age children are particularly affected by this tendency (Sivaramakrishnan & Kamath, 2012).

As urban India goes through a dietary shift, people are becoming more conscious of the importance of breakfast not just as a daily meal, but also as a means of providing the body with essential nutrients. An increasing number of people are beginning to understand how important it is to eat meals that are supplemented with vital vitamins and minerals. Nevertheless, traditional cooking methods have significantly decreased as a result of the fast-paced urban lifestyle, which is typified by long workdays, stressful commutes, and time limits. Consequently, the consumption of ready-to-eat, easy food products has increased significantly (Padmalini et al., 2023) (Paul & Paul, 2023).

There are important ramifications to this change in eating habits. People of all ages frequently find it difficult to maintain regular and timely eating habits because of their hectic and demanding daily schedules. Breakfast has consequently become the most commonly skipped meal, which raises the risk of long-term health issues and a number of nutritional imbalances. Improving the nutritional status of urban populations and encouraging better lives may be greatly aided by addressing this issue through the creation of quick, nutrient-dense breakfast options (Paul, S., & Paul, S, 2023) and (Bhavani, V., & Devi, N. P, 2021).

Clitoria ternatea, commonly known as Blue Pea Flower, is a flowering plant belonging to the Fabaceae family India, the Philippines, Australia, Sri Lanka, South Africa, Indonesia, Malaysia, and various nations bordering the Indian Ocean are among the tropical and subtropical regions where this species is widely spread (Weerasinghe et al., 2022). There are roughly 58 species in the genus Clitoria, with Clitoria ternatea being the most widely used in both traditional and commercial settings.

This plant is valued for its many edible parts, including seeds, leaves, petals, and roots, which are widely employed in traditional medicine, cooking, and even religious ceremonies. In many Southeast Asian cuisines, the leaves in particular are eaten as a side dish (Weerasinghe et al., 2022).

The tropical leguminous plant Clitoria ternatea is well-known for its resilience to harsh weather, including drought, and it grows best in temperatures between 19°C to 28°C. Under the right climatic conditions, it can survive and produce for about 7 to 8 months despite having a very short life cycle (Oguis et al., 2019).

Several regional and vernacular names for this plant include, such as "blue pea," "butterfly pea," "bluebellvine," "Cordofan pea," "Chandra Kanta," and "Asian pigeonwings," the latter of which is the commonly used English name (Vidana Gamage et al., 2021). It is especially valued as a natural food coloring because of its vivid deep blue petals. Numerous food and beverage applications use its aqueous extract as a natural colorant (Chusak et al., 2019).

Clitoria ternatea is known for its remarkable nutritional and pharmacological profile in addition to its culinary applications. In addition to being abundant in bioactive phytochemicals such as polyphenols, phenolic acids, flavonoids, alkaloids, tannins, lignans, coumarins, and terpenoids, the flower is also high in vitamins A, B, C, and E (Jeyaraj et al., 2021). Numerous medicinal advantages are provided by these substances, most notably anti-inflammatory, anti-cancer, antibacterial, and antioxidant properties. In order to fight oxidative stress and delay the onset of chronic diseases like diabetes, cardiovascular disorders, and cancer, anthocyanins a type of flavonoid that gives skin its blue colour are essential (Barik et al., 2007) (Oguis et al., 2019) (Jeyaraj et al., 2021).

In addition, *Clitoria ternatea* has demonstrated several other health-promoting properties. Regular consumption of its extracts has been shown to aid digestion, regulate blood pressure, improve visual health, and exhibit anti-aging effects due to its free radical scavenging ability (Barik et al., 2007) (Oguis et al., 2019). The plant's diverse bioactive compounds such as glycosides, steroids, resins, and phenols have been investigated for their antidiabetic, analgesic, antibacterial, and anti-inflammatory effects (Chusak et al., 2019) (Gupta et al., 2010).

Clitoria ternatea has long been considered a powerful therapeutic herb in traditional Indian medicine, especially Ayurveda. Nootropic (cognitive-enhancing), antipyretic (fever-reducing), antidepressant, anaesthetic, antistress, anxiolytic (anxiety-reducing), insecticidal, anticonvulsant, and diuretic qualities are just a few of its many pharmacological effects (Saptarini et al., 2015).

Clitoria ternatea has garnered significant scientific attention in recent years, and studies are being conducted to identify potential medicinal ingredients for the creation of pharmaceutical and nutraceutical products. One common contemporary application is Blue Pea Tea, a herbal infusion devoid of caffeine that has become very well-liked in Asian markets due to its health advantages and colourful appearance (Weerasinghe et al., 2022).

Thus, Clitoria ternatea makes a strong case as a multipurpose plant that offers a variety of health-promoting bioactive components that promote its usage in the food, pharmaceutical, and wellness industries in addition to its culinary and aesthetic value.

The term *extrusion* originates from the Latin word *extrudere*, meaning “to thrust out” or “to force out.” In industrial applications, extrusion refers to a process in which materials such as metals, plastics, or food ingredients—are pushed through a die or orifice under high pressure and temperature to produce products of specific shapes. In the food industry, this process is known as *food extrusion* (Riaz, 2019).

Food extrusion is a thermomechanical process in which food materials are forced through a shaped opening (die) under controlled conditions. This process turns raw materials into expanded or non-expanded food items by combining heat, pressure, and mechanical shear (Alam et al., 2016). In particular, extrusion cooking is a high-temperature, short-time (HTST) processing technique that involves plasticizing and cooking foods high in protein and/or starch inside a barrel. To create a product with a predetermined shape and texture, the material is subsequently pressed through a die (Harper, 2019) (Riaz, 2019).

This process triggers multiple physical and chemical changes including gelatinization of starch, protein denaturation, caramelization, plasticization, kneading, shearing, and moisture evaporation (Aktas-Akyildiz et al., 2020) (Yu, 2011). The final product's structure, texture, and nutritional qualities are the result of these modifications.

Because of its adaptability, extrusion technology is now used in the food industry for a variety of purposes, such as co-extrusion, heating, cooling, flavour development, encapsulating, shape, mixing, and venting volatiles (Menis-Henrique et al., 2020). It is one of the most crucial technologies in contemporary food processing because it reduces nutritional losses while enabling the creation of shelf-stable, consumable products.

A feed hopper is used to introduce raw materials into the extruder barrel during the extrusion operation. The material is moved forward by a revolving screw. Through a combination of electrical and frictional heat, the narrower screw flights create resistance as the food passes through the barrel, compressing the material and turning it into a semi-solid plasticized mass. Smaller screw flights produce more shear and pressure toward the discharge end, which makes the last phases of cooking and shaping easier. When the cooked material is ultimately squeezed through the die opening, the abrupt drop in pressure causes the moisture to evaporate quickly as steam, which causes the material to expand and cool. The product assumes its final shape depending on the die design, which may include rods, spheres, tubes, rings, shells, and more (Rizvi et al., 1995).

By modifying its structure through hydrothermal treatments, extrusion cooking is a promising and possible method to create ready-to-eat and ready-to-cook foods with functional qualities without compromising nutritional bioavailability. Because different ingredients, particularly plant-derived byproducts, can be used successfully to create innovative value-added goods, the product created by extrusion is becoming more and more popular in the food business (Prabha et al., 2021).

Millets, sometimes referred to as genuine grasses, are a family of small to medium-sized cereal grains. For ages, people have grown these grains in tropical and subtropical areas, especially in Australia, Malaysia, Sri Lanka, China, India, and portions of Africa (Baltensperger, 1996). Millets are renowned for their exceptional drought resilience, short growing season, and high degree of adaptability to arid and semi-arid areas. They are also a sustainable food grain in marginal agricultural areas due to their long storage life and reduced susceptibility to pest infestations (Adekunle, 2012).

Agronomically, millets are resilient, tiny-seeded annual grasses that need little outside assistance to flourish in infertile soils. They can be grown with less dependence on artificial fertilizers and pesticides because of their resilience to common illnesses and pests (Gopalan & Shastri, 2009). Depending on how widely they are grown and consumed, millets are frequently divided into two major and minor categories.

The major millets include, Pearl millet (*Pennisetum glaucum*), Foxtail millet (*Setaria italica*), Proso millet or white millet (*Panicum miliaceum*), Finger millet (*Eleusine coracana*). The minor millets consist of- Barnyard millet (*Echinochloa spp.*), Kodo millet (*Paspalum scrobiculatum*), Little millet (*Panicum sumatrense*), Browntop millet (*Urochloa ramose* / *Brachiaria ramose* / *Panicum ramosum*) (Chinchole et al., 2017) (ICRISAT, 2017) (Yang et al., 2012) (Nithiyanantham et al., 2019).

The main growing regions for millet worldwide are southern Russia, China, Africa, and northern India. According to Sindhu and Khetarpaul (2001), almost 80% of the millet produced worldwide is directly consumed as food, particularly in rural and tribal areas. Despite being grown all year round in India, millet production is still quite small when compared to other cereal grains. However, compared to main cereals and grains, minor millets such as foxtail, tiny millet, and kodo are more affordable and easier to find.

Millets are receiving more attention in the nutrition field because of their low phytic acid level, which improves mineral absorption, and their rich composition of vital micronutrients like iron and B-complex vitamins. Because of these qualities, millets are especially helpful in treating iron-deficiency anemia and other nutritional deficiencies that are common in underdeveloped nations (Malathi et al., 2012).

Finger millet (Eleusine coracana), kodo millet (Paspalum scrobiculatum), foxtail millet (Setaria italica), proso millet (Panicum miliaceum), and little millet (Panicum sumatrense) are among the small millets that India is known for producing more than any other country in the world. An estimated 2.5 million hectares are covered by these crops together each year. Of them, finger millet is the most common, making up between 40 and 50 percent of the total area planted to millet worldwide (Das et al., 2024) (ICRISAT, 2017). Karnataka is the state that produces the most finger millet in India, accounting for over 58% of the total production (Das et al., 2024). Compared to several other cereal grains, such as wheat, maize, rice, and sorghum, finger millet is more nutritious. It is particularly high in resistant starch and slowly digested starch (SDS), which helps control blood sugar levels. Additionally, finger millet's seed coat is very rich in minerals and phenolic compounds, providing strong antioxidant qualities and practical health advantages (Shobana et al., 2013).

Popping, a dry-heat treatment that causes the grains to burst open and puff, is one of the traditional processing techniques used with finger millet. This process improves the grain's palatability and sensory qualities. Popping is accomplished by subjecting the grains to a dry, high-temperature environment usually in a hot pan or skillet while swirling constantly to prevent burning. The end product is a crunchy, light product that can be added to salads, soups, or morning cereals, or eaten as a snack (Das et al., 2024) (Gull et al., 2014). In addition to improving texture, this technique can decrease antinutritional agents and boost the bioavailability of several minerals.

Finger millet's significance goes beyond just its nutritional value. It has great promise for preventing malnutrition, especially in susceptible groups like children and expectant mothers. Its gluten-free status and high calcium and iron content make it a good dietary addition for people with celiac disease or gluten intolerance (Malleshi, 2007) (Devi et al., 2011). Additionally, adding finger millet to value-added goods encourages sustainable farming methods, diversifies diets, and improves rural lives by helping out local farmers (Das et al., 2024) (Rao et al., 2017). Food and nutritional security in India and other millet-producing countries can thus be greatly enhanced by the incorporation of finger millet into conventional food systems.

Common names for kodo millet (Paspalum scrobiculatum L.), a plant in the Poaceae family, include ditch millet and cow grass. Madhya Pradesh is the state that produces the most of this significant minor millet crop, which is mostly grown in India. About 50% of the country's land and 35% of its millet output are in the state (Bhat et al., 2017) Balasubramanian, 2013) (Devi et al., 2014).

The remarkable drought tolerance of Kodo millet, which outperforms that of the majority of other small millets, is one of its most distinctive qualities. Because of its very short growing season (80–135 days), it may adapt well to marginal lands and unpredictable rainfall (Ravi, 2004) (Saxena et al., 2018). The plant usually reaches a height of roughly 90 cm and grows as an annual grass. Because of its capacity to flourish on low soils and require little agricultural inputs, Kodo millet is mostly grown in Gujarat, Karnataka, Chhattisgarh, Eastern Madhya Pradesh, and portions of Tamil Nadu. It is grown throughout the world in places like China, Russia, Japan, and parts of Africa, where it is a staple of traditional food systems.

Kodo millet is one of the millets that have gained popularity recently as sustainable substitutes for staple grains like wheat and rice. Their capacity to endure harsh weather conditions, support climate-resilient farming, and help solve the world's food security issues are the main causes of this change (International Journal of Current Microbiology and Applied Sciences, 2021).

Improved textural qualities and expansion characteristics have been demonstrated in the creation of morning cereals utilizing modified Kodo millet flour, such as that processed by Dry Heat Treatment (DHT20 for 4 hours), improving the end product's sensory and functional profile. These developments not only help millets become more valuable and marketable, but they also promote the larger objectives of environmental preservation and sustainable food systems (Gaurav et al., 2024).

When milk proteins are divided into two main categories during the cheese-making process casein and whey proteins (mostly lactalbumin and lactoglobulin) whey is a by-product. Casein forms the curd during this separation, and the liquid fraction that remains is known as whey because it contains lactose, whey proteins, vitamins, and minerals (Ugwu, Tokiwa, & Aoyagi, 2012). Whey, which was once thought of as waste, has drawn more attention recently because of its high nutritional content, useful qualities, and ability to lessen environmental pollution through correct usage. Untreated whey disposal in open spaces, like soil and water bodies, has raised serious ecological concerns because it causes eutrophication and biochemical oxygen demand (BOD) (Ugwu et al., 2012).

Whey has been investigated as a useful component in the creation of functional food items to address the issues of nutrition and the environment. Extrusion technology, which allows the conversion of agricultural and food processing by-products like whey, broken rice grains, and passion fruit peel into value-added, industrialized food items like ready-to-eat breakfast cereals, is one of the creative approaches in this context (Santos, Caliari, Soares Júnior, Viana, & Leite, 2015). These cereals' convenience, variety of flavors and shapes, and improved nutritional profiles make them especially popular with kids, athletes, and busy customers.

Whey protein (WP) has shown a number of useful advantages when added to extruded morning cereal compositions. Interestingly, WP helps raise the final product's moisture content after extrusion. Lactose's hygroscopic properties, which keep moisture in the product matrix, are primarily responsible for this effect (Santos et al., 2019). Whey proteins are a promising choice for creating nutrient-dense cereals aimed at particular demographics, such as kids, athletes, and people with high-protein dietary needs, because they are known to improve the protein quality, amino acid composition, and functional qualities of extruded foods in addition to texture and moisture regulation.

Rationale of the Study

Modern urban lifestyles have led to the widespread habit of breakfast skipping and poor dietary choices, especially among youth and working individuals. This pattern contributes to micronutrient deficiencies, impaired metabolic health, and increased susceptibility to non-communicable diseases. While traditional breakfast options are nutritious, they often require time and preparation-barriers in today's fast-paced routines.

Meanwhile, the commercial breakfast cereal market in India is saturated with refined grains, added sugars, and synthetic additives, with limited availability of cereals made from indigenous, functional, and sustainable ingredients. There exists a critical gap in the availability of nutrient-dense, antioxidant-rich, and convenient breakfast solutions tailored to the Indian context.

To bridge this gap, this study focuses on developing a Blue Pea Flower Enriched Extruded Millet and Milk Protein- Based Breakfast Cereal referred to as Smarties The product aims to:

- Promote the integration of locally grown millets and functional botanicals into mainstream diets.
- Leverage the nutritional potential of Clitoria ternatea and its antioxidant properties.
- Incorporate whey protein to address protein insufficiency, particularly in vulnerable and active groups.
- Utilize extrusion technology to create a convenient, shelf-stable product suitable for modern Indian consumers.

Furthermore, the study explores the real-world application of Smurfies by incorporating them into common breakfast recipes such as parfaits, granolas, and smoothies, followed by sensory evaluations to assess acceptability. By doing so, the research not only contributes to the body of knowledge on functional food product development but also addresses broader public health objectives, including nutritional security, sustainability and dietary diversification.

BROAD OBJECTIVE

To develop and evaluate extruded breakfast cereals incorporating Blue Pea flower (Clitoria ternatea), millets and milk protein, with an emphasis on assessing their antioxidant properties, glycemic index, sensory characteristics, nutritional profile and shelf life.

SPECIFIC OBJECTIVES

The study outlines phase-wise specific objectives

Phase I (a). Market survey-

1. To identify and analyse existing and similar breakfast cereal products
2. To compare the ingredient composition of available breakfast cereals
3. To evaluate the nutrient composition of existing breakfast cereals
4. To analyse the cost structure of existing products

Phase 1 (b). Development of Blue Pea incorporated Smurfies

1. To choose appropriate components, including the types of millet, milk protein and Blue Pea Flower (Clitoria ternatea) fir creating Smurfies
2. To obtain high-quality ingredients that meet the formulation requirements for the cereal.
3. To develop a cohesive extruded product by combining millet and milk protein, incorporating BPF at three varying levels, utilizing extrusion process technology

Phase II (a). Chemical, organoleptical, physical, microbial, cost analysis and shelf-life study of the Smurfies

1. To analyse the chemical composition and antioxidant profile of Smurfies (proximate principles)
2. To assess textural properties
3. To perform a cost analysis
4. To evaluate the shelf life under storage conditions

Phase II (b). Glycaemic index study of the Smurfies

1. To determine the glycaemic index of the BPF incorporated millet and milk-protein based Smurfies

Phase III (a). Create breakfast recipes featuring Smurfies as a key ingredient

1. To develop breakfast recipes incorporating Smurfies as a key ingredient

Phase III (b). Conducting sensory evaluation of the developed recipes

1. To evaluate the sensory attributes (taste, texture, appearance and overall acceptability) of the developed recipes
2. To assess consumer preference and acceptability of the Smurfies-based breakfast recipes through sensory evaluation trials.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

The formulation and development of functional food products have gained considerable momentum in recent years, driven by increased consumer awareness of the link between diet and long-term health outcomes (Bigliardi & Galati, 2013). As dietary habits evolve due to urbanization, globalization and changes in lifestyle, there has been a notable shift from traditional home-cooked meals to convenient, ready-to-eat options. Among these, breakfast cereals have emerged as a preferred choice in many urban households due to their ease of preparation, extended shelf life and perceived health benefits (Poddar, 2024).

The global rise in non-communicable diseases (NCDs)—including obesity, type 2 diabetes and cardiovascular disorders—has placed increased emphasis on preventive nutrition and functional foods. These foods are designed not only to meet basic nutritional needs but also to provide added health benefits through bioactive components such as dietary fiber, plant antioxidants, probiotics and protein concentrates (Sen & Chakraborty, 2017). However, integrating these components into widely accepted food products requires addressing challenges related to sensory appeal, processing compatibility and cost-effectiveness (Martins et al., 1997).

Cereal-based products, particularly extruded breakfast cereals, serve as an effective vehicle for nutritional enhancement due to their versatility and wide consumer base. Recent efforts have focused on incorporating indigenous grains like millets, whey protein concentrate (WPC-80) and botanicals such as blue pea flower (Clitoria ternatea) into breakfast foods, offering potential solutions to both nutritional deficiencies and lifestyle-related diseases (Chand & Thapak, 2023; Patil et al., 2023; Gokhale et al., 2021). These ingredients are rich in protein, fiber, antioxidants and minerals and are increasingly being explored for their health-promoting properties in functional food development.

Despite promising findings, the success of such innovations depends heavily on achieving a balance between nutritional value and consumer acceptability, particularly in terms of taste, texture and appearance (Rotela et al., 2021). Additionally, extrusion technology has emerged as a leading technique for developing shelf-stable, nutrient-rich products while retaining functional bioactives (Riaz, 2000; Guy, 2001). However, the potential loss of sensitive nutrients and changes in sensory characteristics during processing must be carefully managed.

This chapter presents a comprehensive review of literature related to breakfast consumption patterns globally and in India, the health implications of breakfast skipping, trends in the ready-to-eat cereal market and the nutritional, functional and sensory attributes of selected ingredients. It also highlights research on extrusion processing, market dynamics and the integration of functional ingredients to provide a foundation for the present study.

Breakfast consumption habits show significant variation across the globe, shaped by diverse cultural, socio-economic and lifestyle factors. In many high-income and developed countries, such as the United States, Australia and parts of Europe, breakfast is traditionally emphasized as the most important meal of the day, aimed at providing essential nutrients and supporting cognitive and metabolic functions throughout the day (Rampersaud et al., 2005). Despite this recognition, an increasing trend of breakfast skipping has been observed, particularly among adolescents and young adults. A systematic review conducted by Deshmukh-Taskar et al. (2010) reported that breakfast skipping is widespread among youth, with estimates ranging from 10% to 30%, depending on the region and age group.

This growing tendency to skip breakfast has raised public health concerns due to its association with a higher risk of non-communicable diseases (NCDs). Numerous studies have shown that individuals who regularly skip breakfast are more likely to have poor diet quality, increased body mass index (BMI) and a greater likelihood of developing conditions such as obesity, type 2 diabetes mellitus and cardiovascular disease (CVD) (Uzhova et al., 2017; Smith et al., 2010). For instance, Uzhova et al. (2017) found that skipping breakfast was significantly associated with a higher prevalence of atherosclerosis, an early indicator of cardiovascular risk. Similarly, a cohort study by Mekary et al. (2013) found that men who skipped breakfast had a 27% higher risk of developing coronary heart disease compared to those who regularly consumed breakfast.

In the Indian context, evolving dietary habits and urban lifestyles have contributed to a troubling pattern in breakfast consumption. According to the India Breakfast Habits Study (Kellogg India, 2014), which surveyed urban populations across four major metropolitan cities (Delhi, Mumbai, Chennai and Kolkata), nearly 25% of respondents reported skipping breakfast regularly and approximately 72% consumed breakfasts that were nutritionally inadequate. These breakfasts were often high in refined carbohydrates and low in essential nutrients such as fiber, vitamins (especially B-complex and vitamin C) and minerals like calcium and iron, which are critical for maintaining metabolic health and preventing chronic diseases.

The study also revealed a low awareness of the nutritional importance of breakfast, with only 3% of the surveyed population recognizing breakfast as an essential meal of the day. This lack of awareness reflects a broader gap in nutritional literacy and suggests the influence of time constraints, work-related stress and socio-cultural perceptions that deprioritize morning meals, particularly among working professionals and students (Sharma et al., 2019).

Further research indicates that irregular or skipped breakfasts among Indian adolescents and young adults are associated with increased rates of overweight and obesity, along with poor academic performance and lower physical activity levels (Meshram et al., 2021). These dietary patterns contribute to the growing prevalence of non-communicable diseases (NCDs) in India, including type 2 diabetes, cardiovascular diseases and metabolic syndrome. The Indian Council of Medical Research (ICMR) has highlighted that over 56% of the country's disease burden is linked to poor dietary habits, including breakfast skipping and consumption of energy-dense, nutrient-poor foods (ICMR-NIN, 2023).

Over the past few decades, India has also witnessed a significant transformation in breakfast consumption patterns, particularly in urban areas. This shift from traditional, home-cooked breakfasts to ready-to-eat (RTE) cereals and convenience foods is driven by various socio-economic factors, including urbanization, changing lifestyles and evolving consumer preferences.

Traditional Breakfast Patterns in India

India’s culinary landscape boasts a rich variety of traditional breakfast options that are deeply embedded in regional cultures and socio-economic contexts. Historically, Indian breakfasts have been freshly prepared, hot meals using local grains, legumes, dairy and vegetables. For example:

- South Indian breakfasts include dishes like idli, dosa, upma and pongal, typically rich in fermented foods and lentils.
- North Indian regions favour parathas, poha, cheela and halwa, accompanied by curd or pickles.
- In the West and East, dishes like dhokla, thepla, puffed rice mixes, or luchi with sabzi are common.

These meals offer a balanced mix of carbohydrates, proteins, fibres and micronutrients and are often considered more satiating compared to modern packaged foods (National Institute of Nutrition [NIN], 2011). They also play an important social role, often involving family-based preparation and shared mealtimes. According to the latest edition (2024) of the book *"Dietary Guidelines for Indians"*published by the Indian Council of Medical Research (ICMR), the suggested calorie intake for breakfast for a normally nourished sedentary man weighing 65 kg and having a BMI between 18.5 and 23 kg/m^2 is approximately 570 kilocalories. This recommendation is based on a total daily energy requirement of 2080 kilocalories, with a crude protein intake of 72 grams per day. And the recommended calorie intake for breakfast for a normally nourished sedentary woman weighing 55 kg and having a BMI between 18.5 and 23 kg/m^2 is around 470 kilocalories. This recommendation is derived from a total daily energy requirement of 1660 kilocalories, along with a daily crude protein intake of 57 grams.

The late 1990s and early 2000s marked a major socio-economic transformation in urban India, driven by globalization, increasing nuclear families, dual-income house-holds and fast-paced urban life. As a result, Indian consumers began seeking quick and convenient food options that required minimal preparation (Kaur et al., 2018).

This led to the emergence and growth of the packaged breakfast market. The *India Breakfast Habits Study* (Kellogg's, 2014) found that one in four urban Indians skip breakfast due to lack of time and only 3% consider it the most important meal of the day.

RTE cereals, introduced in India in the early 1990s by brands like Kellogg's, PepsiCo's Quakerand Nestlé, began to capitalize on this shift. Market research reports suggest that the Indian breakfast cereal market was valued at □1,400 crore in 2022, growing at a CAGR of over 18% (Mordor Intelligence, 2023).

RTE cereals, such as cornflakes, oats and muesli, are heavily marketed as healthy, time-saving and energy-rich options. They appeal especially to urban youth and working professionals who prioritize efficiency and portability over traditional meal preparation. For instance, Kellogg's India adapted their offerings to include local flavors (e.g., mango, honey almond) and encouraged consumption with warm milk to suit Indian palates (Sridharan, 2017).

Factors Driving the Shift to R-T-E

a. Time Constraints and Convenience:
The most cited reason for this shift is lack of time in the morning, especially among working adults and students (Vora & Dubey, 2023). RTE cereals require no cooking, making them highly appealing for rushed routines.

b. Perceived Health Benefits:
Modern cereal brands position themselves as low-fat, high-fiber and fortified with vitamins and minerals, influencing consumer behaviour, especially among health-conscious urbanites.

c. Western Influence and Globalization:
There has been a cultural shift, particularly in Tier-1 cities, towards adopting western food patterns. Breakfast, once a culturally grounded ritual, is now increasingly seen as a functional necessity.

d. Changing Family Structures:
With fewer joint families and more individuals living alone or as nuclear units, the tradition of elaborate cooking is slowly diminishing (Kaur & Kapoor, 2018).

While RTE cereals are marketed as healthy, nutritionists argue that many commercial cereals are high in added sugars, sodium and low in protein, particularly when consumed with skim milk or without other nutrient-dense accompaniments (Misra et al., 2019). Moreover, the loss of traditional fermented foods (such as idli/dosa batter or curd) in daily diets may negatively affect gut health and immunity.

Culturally, this transition marks a shift away from inter-generational food practices and local food wisdom. Traditional breakfasts, once tailored to seasonal and regional needs, are increasingly replaced by standardized, mass-produced food with limited diversity (ICMR-NIN, 2023)

In conclusion, the shift from traditional Indian breakfasts to RTE cereals is a classic example of how urbanization and modernization impact dietary patterns. While this transition offers convenience and modern appeal, it comes at a cost—potential nutritional compromise and loss of culinary heritage. Public health efforts should aim to re-educate consumers about balanced breakfasts and encourage innovations that integrate tradition with convenience.

The consumption of breakfast cereals has become widespread globally, often perceived as a convenient and healthy start to the day. However, concerns have been raised regarding their nutritional composition, particularly the high glycaemic index (GI), added sugars, artificial additives and refined flours and their association with non-communicable diseases (NCDs) such as obesity, type 2 diabetes and cardiovascular diseases.

High Glycaemic Index and Refined Flours

Many breakfast cereals are produced using refined flours, which lack the fiber and nutrients found in whole grains. The refining process removes the bran and germ, leading to a higher glycaemic index. Consumption of high-GI foods causes rapid spikes in blood glucose levels, which over time can lead to insulin resistance, a precursor to type 2 diabetes. A review highlighted that the consumption of whole cereals is associated with a reduced risk of type 2 diabetes, whereas refined cereals may contribute to its development (Wu et al., 2019).

Added Sugars and Sweeteners

Breakfast cereals, especially those marketed to children, often contain significant amounts of added sugars to enhance flavour. An analysis of breakfast cereals revealed that only 8.7% of products met national guidelines of containing less than 5g of sugar per 100g, with some cereals containing up to 45.2g of sugar per 100g. Excessive sugar intake is linked to an increased risk of obesity, type 2 diabetes and dental caries. Additionally, high sugar content in cereals can displace more nutrient-dense foods from the diet, leading to overall poor nutrition. (Prada et al., 2021)

Artificial Additives and Colours

To enhance visual appeal and shelf life, manufacturers often incorporate artificial colours and additives into breakfast cereals. For instance, cereals like Froot Loops contain additives such as Red 40, which has been linked to behavioural issues in children. Moreover, some additives have been associated with adverse health effects, prompting calls for their removal from food products.

Ultra-Processed Nature of Breakfast Cereals

Breakfast cereals are often classified as ultra-processed foods (UPFs), characterized by the inclusion of ingredients not commonly found in home cooking, such as preservatives, emulsifiers and artificial flavours. A study involving nearly ten million participants found that high consumption of UPFs is associated with an increased risk of various NCDs, including cancer, diabetes, heart disease and mental health disorders. The study emphasizes the health benefits of minimizing UPF consumption and opting for whole, minimally processed foods.

Market Trends and Consumer Awareness

Despite the health concerns, the breakfast cereal market continues to grow, driven by consumer demand for convenience. However, there is a growing awareness and demand for healthier options, leading some manufacturers to reformulate products with whole grains, reduced sugarsand natural additives. Nevertheless, a significant portion of the market still comprises products with high levels of refined ingredients and additives.

Functional Ingredient Integration in Traditional Dishes

Functional foods are developed to provide health benefits beyond basic nutritional needs, addressing issues such as malnutrition, non-communicable diseases (NCDs)and lifestyle-related disorders (Bigliardi & Galati, 2013). Recent research underscores the value of incorporating functional components including dietary fiber, high-quality proteins, antioxidants and plant-based bio actives into familiar traditional food forms to enhance consumer acceptance and adherence (Poddar, 2024; Sen & Chakraborty, 2017).

However, a significant hurdle in functional food development remains sensory acceptability. Nutritionally enhanced products often face rejection if their taste, texture, or appearance deviates from consumer expectations (Martins et al., 1997). Ingredients such as whey protein, flaxseed powder, or butterfly pea (blue pea) flower, while rich in nutritional value, may affect the colour, mouthfeel, or aroma of the final product. Therefore, ensuring a harmonious balance between nutritional enhancement and sensory appeal is essential.

Despite growing interest in health-oriented traditional foods, there is limited literature that holistically explores the incorporation of multiple functional ingredients—such as the combined use of proteins, fibres and botanicals—within conventional food matrices, while simultaneously evaluating their functional and sensory attributes. Much of the current research tends to focus on either the nutritional benefits or sensory qualities, without addressing both in an integrated framework.

Recent studies advocate for interdisciplinary collaboration—bringing together food technologists, dietitians and culinary professionals—to create culturally relevant, value-added traditional foods that are both health-promoting and organoleptically acceptable (Gokhale et al., 2021). Such an approach holds promise for transforming public health nutrition by leveraging localized and culturally embedded functional food innovations.

Extrusion

Extrusion technology has emerged as a pivotal food processing technique, offering versatility in developing value-added products. It involves the transformation of raw food materials under high temperature and pressure into cooked, shelf-stable and palatable products. The technology is widely used to produce breakfast cereals, snacks, meat analogues, pasta and nutraceutical-enriched products (Brennan et al., 2011).

Extrusion is a High Temperature Short Time (HTST) process wherein food mixtures are passed through a die using a screw mechanism. The raw materials undergo thermal and mechanical energy inputs, resulting in physical and chemical changes such as starch gelatinization, protein denaturation and reduction of anti-nutritional factors (Riaz, 2000). This process not only enhances digestibility but also provides microbial safety and extended shelf life (Fellows, 2009).

Extrusion allows the incorporation of a wide range of ingredients including cereals, legumes, fruits, vegetables and functional compounds like fibres and bio actives. Numerous studies have demonstrated successful development of extruded products with improved protein quality, fiber content and functional properties. For example, Kumar et al. (2017) formulated extruded snacks enriched with soy and dietary fibres, which showed enhanced nutritional profile and consumer acceptability.

Extrusion affects the nutritional composition of foods, often positively by improving protein and starch digestibility and reducing antinutritional compounds. However, losses of heat-sensitive nutrients such as vitamin C and certain B-complex vitamins may occur (Singh et al., 2007). The process also enhances the functional properties like expansion, texture and water absorption, which are critical for consumer preference (Alam et al., 2016).

Modern extrusion techniques such as twin-screw extrusion and cold extrusion have enabled the production of diverse functional foods with retained bioactivity. Moreover, the integration of extrusion with 3D printing technology has opened new avenues in customized food production (Severini et al., 2016). These advances help address consumer demands for health-oriented and convenient food products.

Extrusion is considered an environmentally sustainable technology due to its energy efficiency and minimal water usage. It aligns with the goals of clean label products and waste minimization in the food industry (Guy, 2001).

Millets

Millets, often termed as “nutri-cereals,” are ancient grains recognized for their high nutritional value, particularly their abundance of micronutrients. These cereals have garnered attention for their potential role in addressing malnutrition, especially within resource-constrained populations. As reported by Chand and Thapak (2023), millets account for up to 60% of the total energy intake in rural Indian diets, reflecting their critical role in regional food security. Comparative studies by Jagati et al. (2021) have revealed that finger millet, for instance, possesses significantly higher levels of calcium and iron compared to conventional staples like rice and wheat.

The integration of millets into traditional dietary patterns has been shown to diversify meal composition and enhance nutritional adequacy (Hassan et al., 2021; Patil et al., 2023). Beyond their macronutrient and micronutrient content, millets are also gaining recognition for their functional properties. Research by Amadou (2022) highlights the presence of prebiotic components in millets that can support gut health. Additionally, the synergistic blending of millets with pulses has been found to improve the protein quality of meals, as demonstrated by Rotela et al. (2021).

Despite substantial research on the nutritional merits of millets, limited studies have explored their incorporation into innovative processed food products. This presents opportunities for further investigation into millet-based product development, particularly in the context of modern food systems and consumer demands for functional and convenient nutrition.

Botanically, millets belong to the grass family *Poaceae* and are among the earliest domesticated crops. Although often categorized as “minor cereals,” they hold significant value in traditional agriculture, particularly in Asia and Africa, where they have long served as a staple for both humans and livestock (Jagati et al., 2021). Their ability to thrive in poor soils with minimal water and agricultural inputs has earned them the reputation of being a “poor man’s crop.”

Millets are highly adaptable to tropical and subtropical agro-climatic zones and are largely cultivated under rainfed conditions. Their resilience to climatic stress, minimal requirement for chemical inputs and short cropping duration (typically 2–4 months) make them ideal for sustainable and dryland farming systems. These characteristics also align them with modern agricultural goals focused on climate resilience and ecological sustainability.

Traditionally cultivated during the kharif season, millets grow well with annual rainfall exceeding 450 mm and can yield effectively even in high-temperature environments. Moreover, certain varieties, such as foxtail millet, exhibit natural resistance to pests and are utilized as bio-preservatives in grain storage, reducing the need for chemical fumigation. This pest-resistance attribute enhances the ecological appeal of millet farming.

Although millets currently represent a smaller share of staple food crops within Indian agriculture, their contribution to regional food and nutrition security is gaining recognition. As emphasized by Prasanthi and Sireesha (2022), millets play a crucial role in promoting agricultural sustainability and dietary diversification in the face of contemporary nutritional and environmental challenges.

Finger Millet

Finger millet, commonly known as *ragi* in India, is an ancient cereal grain of high nutritional and therapeutic importance. Belonging to the Poaceae family, it is widely cultivated in arid and semi-arid regions of Asia and Africa and is considered a climate-resilient crop due to its ability to thrive under minimal water and input conditions (Devi et al., 2011).

Nutritional Composition

Finger millet is renowned for its superior nutritional profile. It contains 7–8% protein, 1.3–1.8% fat and is an excellent source of dietary fiber (15–20%) (Shobana et al., 2013). It stands out among cereals due to its exceptionally high calcium content, ranging from 344–364 mg/100 g, which is 10 times more than that found in rice or wheat (Hegde et al., 2005). It also contains appreciable amounts of iron, phosphorus and essential amino acids such as methionine, which is typically deficient in other staple cereals.

Health and Functional Benefits

Finger millet exhibits several health-promoting properties, making it an ideal candidate for functional food development. It is rich in polyphenols and dietary fiber, which have been linked to antioxidant, anti-diabetic and hypo-cholesterolemia effects (Chandrasekara & Shahidi, 2011). The grain has a low glycaemic index, which helps in managing blood glucose levels and reducing the risk of type 2 diabetes (Sudha et al., 2007). Its high calcium and phosphorus content also support bone health, making it particularly beneficial for populations at risk of osteoporosis or undernutrition.

Anti-Nutritional Factors and Processing Techniques

Despite its nutritional benefits, finger millet contains anti-nutritional compounds such as phytic acid, tannins and oxalates, which may hinder the bioavailability of minerals. However, traditional processing methods such as soaking, germination, fermentation and roasting have been found to significantly reduce these factors, thereby improving nutrient digestibility and functional attributes (Antony et al., 1996; Krishnan et al., 2012).

Use in Food Product Development

Finger millet's versatility has led to its incorporation in a wide array of traditional and novel food products such as porridges, idlis, dosas, vermicelli, cookies and breakfast cereals. Research by Lakshmi & Sumathi (2002) showed that finger millet-based foods developed for children improved iron status and haemoglobin levels. Moreover, the inclusion of finger millet in bakery and extruded products is gaining popularity due to consumer interest in gluten-free and functional food options (Malleshi & Desikachar, 1981).

Role in Addressing Nutritional Security

As emphasized by Subba Rao et al. (2021), the revival of finger millet cultivation and its integration into national nutrition programs could play a significant role in combating micronutrient deficiencies and ensuring food security in vulnerable populations. Its cultivation also supports sustainable agriculture by improving soil health and requiring minimal inputs.

Figure 2.1 **Finger Millet**

Kodo Millet

Kodo millet (*Paspalum scrobiculatum L.*), a lesser-known yet nutritionally potent grain, is one of the oldest cultivated millets in India. It is primarily grown in the semi-arid and hilly regions of central and southern India and is known for its resilience in poor soil conditions and its ability to thrive in areas with low rainfall (Veena et al., 2005).

Nutritional Profile

Kodo millet is considered a rich source of dietary fiber, polyphenols and complex carbohydrates, making it a low-glycaemic index food suitable for diabetic and health-conscious populations. According to Malleshi (2007), kodo millet contains about 8.3% protein, 1.4% fat, 65.9% carbohydrates and 9% dietary fiber. The presence of significant amounts of minerals like calcium, iron and phosphorus enhances its functional value, especially in combating micronutrient deficiencies (Hadimani & Malleshi, 1993).

Health Benefits and Functional Properties

Research has shown that kodo millet exhibits several health-promoting properties, including anti-diabetic, antioxidant, anti-obesity and anti-hyperlipidaemic effects (Hegde et al., 2005). The grain is particularly beneficial for managing lifestyle disorders such as cardiovascular diseases, diabetes and obesity due to its low-fat content and high dietary fiber. Studies have shown that regular consumption of kodo millet helps in reducing blood sugar and cholesterol levels (Shobana et al., 2009).

Kodo millet also contains high levels of phenolic compounds and flavonoids, which act as natural antioxidants and help mitigate oxidative stress in the human body (Chandrasekara & Shahidi, 2011). Its slow digestibility and high satiety value make it a preferred ingredient in weight management diets (Devi et al., 2011).

Processing and Product Development

Despite its nutritional advantages, kodo millet contains anti-nutritional factors such as phytic acid and tannins, which can reduce the bioavailability of minerals. However, traditional processing methods such as germination, fermentation and roasting have been found effective in minimizing these compounds while improving nutrient absorption (Kumar et al., 2018).

Kodo millet has been incorporated into various traditional and value-added products including porridges, idli, dosa, noodles and baked goods. Dharmaraj & Somashekar

(2020) reported the successful development of extruded snacks and breakfast cereals using kodo millet, with acceptable sensory characteristics and enhanced nutritional value. The growing interest in gluten-free and health-oriented products has further boosted the demand for kodo millet-based food innovations.

Agricultural and Environmental Relevance

From an agronomic perspective, kodo millet is highly drought-tolerant and pest-resistant, making it ideal for cultivation in marginal environments with minimal input. It fits well into sustainable farming systems and is often promoted in dryland agriculture due to its short growth cycle and low water requirement (Balasubramanian et al., 2017). It contributes to both food and livelihood security in tribal and rural regions of India, where it continues to be a dietary staple.

Figure 2.2 Kodo millet

Blue Pea Flower (*Clitoria ternatea*)

Blue pea flower (*Clitoria ternatea* L.), commonly known as butterfly pea, is a medicinal and ornamental plant traditionally used in Ayurvedic and Southeast Asian cultures. In recent years, it has gained considerable attention in food science and nutrition research due to its functional, therapeutic and colorant properties. The vibrant blue anthocyanin-rich extract from its petals makes it not only visually appealing but also a promising ingredient in functional food product development.

Phytochemical Composition and Bioactive Properties

Blue pea flower is rich in polyphenols, particularly anthocyanins, flavonoids and terpenoids, which contribute to its strong antioxidant potential (Yusof et al., 2021). The major anthocyanin compound found in *Clitoria ternatea* is ternatin, a polyacylated anthocyanin responsible for its intense blue hue (Chusri et al., 2018). These compounds have been reported to possess free radical scavenging, anti-inflammatory, anti-diabetic and neuroprotective activities (Mukherjee et al., 2008; Khoo et al., 2017).

Functional and Health-Promoting Effects

Several studies have documented the health benefits of blue pea flower. Yusof et al. (2021) demonstrated that aqueous extracts of the flower exhibit significant antioxidant activity in vitro. In addition, research by Mukherjee et al. (2008) identified *Clitoria ternatea* as having cognitive-enhancing properties due to its modulation of acetylcholine levels, thereby showing potential in managing neurodegenerative disorders.

The plant's hypoglycaemic and lipid-lowering effects have also been reported, making it beneficial in managing metabolic syndrome and type 2 diabetes (Bhandari et al., 2020). Its anti-inflammatory properties further contribute to its therapeutic relevance in functional food formulations.

Application in Food Product Development

The use of blue pea flower in food applications is increasingly being explored, particularly as a natural food colorant and functional ingredient in beverages, teas, desserts, baked goods and health supplements. Its pH-sensitive anthocyanins allow for natural colour transitions (blue to purple to pink), making it useful for innovative and interactive food products (Nguyen et al., 2020).

Despite its promising applications, challenges remain in preserving anthocyanin stability during processing and storage. Encapsulation techniques and pH modulation are being investigated to improve the shelf life and colour retention of blue pea-derived products (Suwannalert et al., 2021).

Integration in Functional and Traditional Foods

Blue pea flower is increasingly being incorporated into culturally familiar foods to improve consumer acceptance of health-oriented innovations. Poddar (2024) highlights its incorporation into composite flour blends for breakfast cereals, enhancing both aesthetic and nutritional properties. However, sensory acceptability can be influenced by changes in colour, aroma and taste—factors that must be optimized during formulation (Martins et al., 1997).

Research Gaps and Future Directions

Although the health-promoting properties of *Clitoria ternatea* are well-documented in vitro, clinical trials and long-term human studies are limited. Furthermore, standardization of extraction, dosage and incorporation methods in food matrices requires further investigation to ensure safety, efficacy and consumer acceptability (Khoo et al., 2017).

Figure 2.3 **Blue Pea Flower Fresh and Dried**

Whey Protein Concentrate (WPC-80)

Whey Protein Concentrate (WPC) is a high-quality dairy-derived protein supplement obtained as a by-product during the cheese-making process. Among its variants, WPC-80, which contains approximately 80% protein by weight, is particularly valued in the food and nutrition industry for its nutritional density, functional versatility and bioactive potential.

Nutritional and Functional Properties

WPC-80 is rich in essential amino acids (EAAs), especially branched-chain amino acids (BCAAs) such as leucine, isoleucine and valine, which play a crucial role in muscle protein synthesis and metabolic regulation (Phillips, 2011). The protein is characterized by high digestibility and biological value, making it superior to many plant-based proteins in terms of amino acid profile and bioavailability (Boirie et al., 1997).

Moreover, WPC-80 retains several bioactive peptides and immunoglobulins that offer health-promoting effects, including immune enhancement, antihypertensive properties and antioxidant activity (Marshall, 2004; Korhonen & Pihlanto, 2007). These properties have made WPC-80 a functional ingredient of interest in both clinical nutrition and sports supplementation.

Applications in Functional and Fortified Foods

WPC-80 has been widely incorporated into functional foods, ready-to-drink beverages, bakery items, breakfast cereals and nutritional bars due to its excellent solubility, emulsifying ability and gelling properties (Sinha et al., 2007). Its role in developing high-protein food formulations is well-documented, with studies highlighting improvements in satiety and muscle maintenance, particularly among athletes, elderly populations and individuals with sarcopenia (Tang et al., 2009; Devries & Phillips, 2015).

In cereal-based products, such as extruded breakfast cereals, WPC-80 contributes to improved protein content, textural characteristics and sensory appeal. However, its inclusion must be balanced to avoid excessive browning (Maillard reaction) and off-flavours, especially during high-heat processing (O'Riordan et al., 2001).

Health Benefits and Clinical Potential

The consumption of WPC-80 has been associated with numerous health benefits. Studies have shown that regular intake can reduce postprandial glucose and insulin levels, indicating its potential in managing type 2 diabetes and metabolic syndrome (Nilsson et al., 2004). Furthermore, WPC-80 has been implicated in reducing blood pressure via bioactive peptides that inhibit angiotensin-converting enzyme (ACE), thus contributing to cardiovascular health (Pal & Ellis, 2010).

Its immunomodulatory properties, attributed to components such as lactoferrin and immunoglobulins, also make it suitable for clinical nutrition in immunocompromised individuals or elderly populations (Ha & Zemel, 2003).

Research Gaps and Future Scope

While the benefits of WPC-80 are well-supported, sensory optimization, cost considerations and consumer acceptability remain key challenges in its incorporation into traditional foods. Further research is required to explore synergistic combinations of WPC-80 with fibres, botanicals and non-dairy matrices, especially in culturally rooted diets.

Table 2.1 Departmental Studies on Recipe Development

Author	Study	Results
Mehta and Shah, 2010	Supplementation of Ragi laddu combined with shankhpushpi was given for four weeks to elderly individuals living in institutional settings.	Increased hemoglobin and calcium levels, improved HDL cholesterol, and reduced LDL cholesterol and TC/HDL ratio. Joint pain and lethargy decreased, while appetite, cognitive performance, and memory retention improved
Nambiar and Sareen, 2012	Assessment of pearl millet-based foods processed using methods such as roasting, soaking, and milling to evaluate iron bioavailability.	Significant improvement in the bioavailability of iron from pearl millet after processing.
Iyer and Dhruv et al., 2012	Kodo millet-based recipes were supplemented to 30 subjects with Type 2 diabetes mellitus for a duration of 28 days.	Recipes showed high acceptability. Participants experienced stable glycemic status (normal FBS and HbA1c), reduction in microalbuminuria (from 37.5% to 21.4%), improved Apo A levels, decreased Apo A/B ratio, and normalization of lipid profile (TC, TG, LDL, VLDL).

Nambiar and Patwardhan, 2013	Study on millet consumption patterns among patients with noncommunicable diseases (NCDs) in Pune, along with glycemic index evaluation of traditional Maharashtrian millet recipes.	Millet consumption was reported by 85% of males and 88% of females but with low daily frequency (<16%). Bajra Vada was most frequently consumed. Bajra Cheela exhibited the lowest GI, whereas Bajra Bhakri had the highest GI.
Nambiar et al., 2015	Exploration of the potential health benefits and functional properties of pearl millet in preventing chronic degenerative diseases.	Pearl millet polyphenols showed protective effects against chronic degenerative diseases.
Gandhi and Parmar, 2017	Survey conducted to understand the importance and consumption patterns of millets in the Panchmahal district.	Awareness primarily limited to Bajri and Kodri. Awareness levels varied: 15% urban, 31% rural, and 27% tribal respondents recognized millet health benefits.
Dhruv and Thite, 2021	Development and sensory evaluation of recipes incorporating foxtail millet.	All developed recipes received good sensory acceptance. Among them, Sev, Chakri, and Idada were especially favored.
Dhruv and Sharma, 2022	Sensory evaluation and product development of recipes containing little millet.	Recipes were widely acceptable, with Bisi Bele Bhaat showing the highest acceptance.
Dhruv and Sharma, 2022	Sensory evaluation and formulation of recipes using Brown Top millet.	All recipes had good sensory acceptability, with Veg Khichdi rated the highest.

MATERIALS AND METHODS

CHAPTER- 3

MATERIALS AND METHODS

The Materials and Methods chapter formed the backbone of this scientific inquiry, offering a clear and systematic account of how the research was conceptualized, conducted and analyzed. A well-structured methodology minimized bias and experimental error, enhancing the reliability and validity of the outcomes while contributing to meaningful scientific progress. This chapter detailed the experimental framework of the study titled "Development and Characterization of *Smurfies:* A Blue Pea Flower (Clitoria ternatea) Powder Enriched Extruded Millet and Milk Protein-based Breakfast Cereal." The primary objective was to develop and evaluate a health-oriented extruded breakfast cereal, named *Smurfies,* enriched with Blue Pea flower, millets and milk protein, focusing on its antioxidant properties, glycaemic index, sensory characteristics, nutritional profile and shelf life. The study began with a market survey followed by the development of the extruded product. It further involved chemical, physical, sensory, microbial, cost and shelf-life evaluations, along with a glycaemic index study. Finally, *Smurfies* -based breakfast recipes were created and assessed through sensory evaluation.

The study was carried out in the following three phases:

PHASE- I (a). Market survey:

1. To identify and analyse existing and similar breakfast cereal products
2. To compare the ingredient composition of available breakfast cereals
3. To evaluate the nutrient composition of existing breakfast cereals
4. To analyse the cost structure of existing products

PHASE I (b). Development of Blue Pea incorporated *Smurfies:*

1. To choose appropriate components, including the types of millet, milk protein and Blue Pea Flower (*Clitoria ternatea*) for creating *Smurfies*
2. To obtain high-quality ingredients that meet the formulation requirements for the cereal

3. To develop a cohesive extruded product by combining millet and milk protein, incorporating Blue Pea Flower (BPF) at three varying levels, utilizing extrusion process technology.

PHASE II (a). Chemical, organoleptic, physical, microbial, cost analysis and shelf-life study of the *Smurfies:*

1. To conduct a sensory evaluation aimed at identifying the optimal level of BPF incorporation based on the highest sensory scores.
2. To analyse the chemical composition and antioxidant profile of *Smurfies* (proximate principles)
3. To assess textural properties
4. To perform a cost analysis
5. To evaluate the shelf life under storage conditions

PHASE II (b). Glycaemic index study of the *Smurfies:*

1. To determine the glycaemic index of the BPF incorporated millet and milk-protein based *Smurfies*

PHASE III (a). Create breakfast recipes featuring *Smurfies* as a key ingredient:

1. To develop breakfast recipes incorporating *Smurfies* as a key ingredient

PHASE III (b). Conducting sensory evaluation of the developed recipes:

1. To evaluate the sensory attributes (taste, texture, appearance and overall acceptability) of the developed recipes
2. To assess consumer preference and acceptability of the *Smurfies* -based breakfast recipes through sensory evaluation trials

The subsequent section provides a detailed account of the various phases of the study, including the study design, as well as the tools and techniques employed throughout the research.

3.1 Product Development Phase

3.1.1 Market Survey of Commercial Breakfast Cereal Products

3.1.2.1 Concept Generation, Screening and Prototype Development

3.1.2.2 Selection of suitable components for the development of *Smurfies*

3.1.2.3 Proximate Analysis of Raw Materials

3.1.2.4 Formulation and Standardization of *Smurfies* with Varying Levels of Blue Pea Flower

3.2 Product Evaluation Phase

3.2.1 Comprehensive Evaluation of *Smurfies:* Chemical, Physical, Microbial, Cost and Shelf-Life Analysis

3.2.1.1 Proximate Principles analysis of the *Smurfies*

3.2.1.2 Antioxidant Profiling of *Smurfies*

3.2.1.3 Textural Characterization of *Smurfies*

3.2.1.4 Microbiological Quality Assessment of *Smurfies*

3.2.1.5 Accelerated Shelf-Life Assessment of *Smurfies*

3.2.1.6 Cost Estimation of *Smurfies*

-3.2.2 Evaluation of Glycaemic index of the Blue Pea flower incorporated *Smurfies*

3.3 Product Application Phase

3.3.1 Development of Breakfast recipes featuring *Smurfies* as a key ingredient

3.3.2 Sensory Assessment of *Smurfies* -Based Breakfast Recipes

Study Locale

An offline market survey was conducted across various locations in Vadodara city, while an online survey was performed using platforms such as Amazon, BigBasket, Blinkit and Swiggy Instamart. The extrusion process was carried out at the SMC College of Dairy Science, Kamdhenu University, Anand. Nutrient and chemical analyses, texture profile analysis and shelf-life evaluation were undertaken at the

National Institute of Food Technology, Entrepreneurship & Management (NIFTEM), (Ministry of Food Processing Industries (MOFPI), Autonomous Institute Under the Government of India), Kundli, Sonipat, Haryana, India. Texture profile analysis was conducted at Hemshell Services, GIDC, Makarpura, Vadodara. Recipe standardization, product preparation, sensory evaluation and glycaemic index assessment of the *Smurfies* were performed at the Department of Foods and Nutrition, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, Vadodara. The antioxidant activity of the *Smurfies,* using the DPPH method, was analyzed at the Department of Biochemistry, Faculty of Science, The Maharaja Sayajirao University of Baroda, Vadodara.

Statutory clearance of the study

The research study received ethical approval from the Institutional Medical Ethics Committee of the Department of Foods and Nutrition, The Maharaja Sayajirao University of Baroda. Clearance was granted under Ethical Clearance Number: IECHR/FCSc/M.Sc./10/2024/44 (Annexures I).

3.1 Market survey and Product Development Phase

The product development phase involved market surveys and formulation trials to create *Smurfies,* a blue pea-enriched, millet and milk protein rich extruded breakfast cereal.

3.1.1 Market Survey of Commercial Breakfast Cereal Products

An extensive market survey was conducted through both offline and online channels to collect data on commercially available breakfast cereals with similar formulations. Various breakfast cereals were identified and analysed based on their nutrient content, ingredient composition and cost structure. The offline market survey encompassed several retail outlets and supermarkets in Vadodara, including D-mart, Star bazar, Reliance SMART superstore, Spencer's, Big Bazar, Magson and lifestyle store like Planet Health and Bansal superstore. Simultaneously, the online market survey was done through e-commerce platforms such as Amazon, Big Basket, Blinkit and Swiggy Instamart. The aim was to gain a surround understanding of different varieties and type of breakfast cereals available in the market and to the consumers.

During the investigation period, a survey was conducted to assess the variety of extruded breakfast cereals available to consumers. The objectives of the survey were as follows:

- To identify and analyze existing breakfast cereal products with similar characteristics
- To compare the ingredient composition of currently available cereals
- To evaluate their nutritional profiles
- To examine the cost structure of these market-available products

A total of 12 brand s comprising 45 extruded breakfast cereal products were surveyed. These products were further categorized based on various parameters, including type of ingredients, net weight, cost, serving size, nutritional composition and shelf life. A schematic representation of the market survey is provided in Figure 3.1.1.

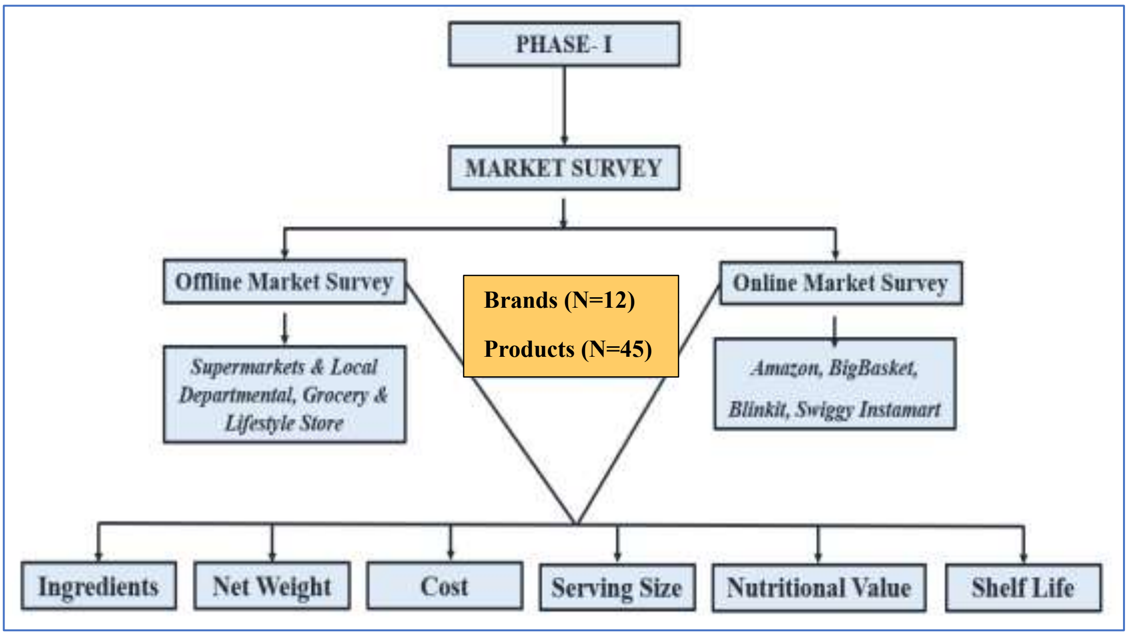

Figure 3.1 Schematic Diagram Representing Survey of Extruded Breakfast Cereal Products

As part of Phase-I of the study, a total of 45 breakfast cereal products from 12 brand s were surveyed and analyzed based on six key parameters: ingredients, net weight, cost, serving size, nutritional value and shelf life. Ingredient lists were reviewed from both physical packaging and online product descriptions to identify primary components such as cereals, protein sources, sweeteners, fats and additives. Net weight was recorded from packaging to classify products based on pack sizes, while cost was standardized per 100g to allow accurate comparison across brands. Serving size information was used to assess portion recommendations and nutrient delivery per serving. Nutritional values, including macronutrient and energy content, were documented per 100g and per serving, with products grouped according to protein content. Shelf-life data were extracted from labels to understand product stability and preservation approaches. This comprehensive parameter-based analysis helped inform the formulation strategy for the development of *Smurfies.*

3.1.2.1 Concept Generation, Screening and Prototype Development

The product development phase began with concept generation, where ideas were brainstormed based on market gaps, nutritional needs and ingredient functionality. These ideas were then screened using feasibility, cost, consumer preference and nutritional adequacy as criteria. The selected concept was further refined into a prototype, incorporating millets, milk protein and blue pea flower. This prototype was tested for texture, appearance and sensory attributes, laying the foundation for the final formulation of *Smurfies.*

3.1.2.2 Selection of suitable components for the development of *Smurfies*

A preliminary market survey was undertaken to source high-quality ingredients, including millets, lyophilized Blue Pea Flower (BPF) and whey protein concentrate (WPC). As a result, premium varieties of Ragi (*Eleusine coracana*) and Kodri (*Paspalum scrobiculatum*) were obtained from the Miltop brand sourced through online market. WPC-80 was sourced online from NAKPRO Nutrition, Bengaluru and Blue Pea Flower (*Clitoria ternatea*) was procured from the brand 'Online Quality Store' (Butterfly Pea Flower Herbal Tea), India. Existing literature highlights that millet-based extruded products are nutrient-dense, protein-rich and well-suited for developing sports foods and protein-energy bars (Baria et al., 2023).

3.1.2.3 Proximate Analysis of Raw Materials

Following selection, all raw ingredients were subjected to proximate analysis to assess their nutritional composition. The Proximate analysis of Ragi, Kodri and Blue Pea Flower was conducted using the standard AOAC protocols. The choice of pearl millet

(*Pennisetum glaucum*) and WPC was also referred by prior research highlighting their synergistic role in improving the nutritional and sensory quality of extruded snacks (Yadav et al., 2014).

3.1.2.4 Standardization and Extrusion Technique for *Smurfies* with Variable Blue Pea Flower Content

The selection of Blue Pea Flower (BPF) incorporation levels and extrusion temperatures in this study was based by the findings of Singh et al. (2022), where BPF was added to Yellow Pea (YP) at concentrations of 0%, 5% and 10% (w/w) and extruded at two temperature settings (130°C and 150°C). Results indicated that higher die temperatures produced extrudates with improved expansion ratios, reduced dry hardness and enhanced crispiness. Furthermore, the inclusion of BPF contributed to a noticeably darker and more intense blue coloration in the extrudates compared to those without BPF.

Preparation of feed mixture formula:

Millets flour, milk protein powder and milled BPF at a varying level of 0 per cent, 5 per cent and 10 per cent (w/w) were mixed and then moistened with up to 10 per cent water of the total flour weight. Raw Materials for the development of *Smurfies* are shown in Figure 3.2. Subsequently, the resulting moistened flour blends (Figure 3.3) underwent a double sieving process to eliminate any coarse or foreign particles that could potentially impede the extrusion process, thereby ensuring smooth operation. The flour blend was then packaged in low-density polyethylene (LDPE) pouches and preconditioned at room temperature for two hours. Table 3.1 outlines the formulation of *Smurfies* through extrusion.

Table 3.1 Formulation of *Smurfies*

Sr. No.	Ragi (*Eleusine coracana*) (g%)	Kodri (*Paspalum scrobiculatum*) (g%)	WPC-80* (g%)	Blue Pea Flower (*Clitoria ternatea*) * (g%)	Salt* (g%)	Vanila Extract* (g%)
1.	70	30	10	0	1	0.4
2.	70	30	10	5	1	0.4
3.	70	30	10	10	1	0.4%

* On flour basis

The twin-screw extruder (TSE) used for developing the product was a co-rotating model (BTPL lab type EB-10, manufactured in Kolkata, India), consisting of three main zones: feeding, heating and die. The extruder barrel was three feet long with a diameter of 40 mm and included a smooth barrel design, temperature control system, variable-speed motor and an integrated cutter. The extrusion process of *Smurfies* and the extruder itself are shown in Figures 3.4 and 3.5, respectively. The final extruded *Smurfies* are displayed in Figure 3.6, while the complete process flow for feed preparation and extrusion is illustrated in Figure 3.7. Following extrusion, the product was air-dried in a hot air oven at 100°C for 30 minutes to remove excess moisture. Annexure II outlines the detailed operational parameters used during the process and the proximate composition of the extrudates is presented in Table 4.2.1 in the subsequent chapter. The tools and techniques used are mentioned in the Table 3.2

Figure 3.2 Raw Materials for the preparation of *Smurfies*

Figure 3.3 Conditioned Feed Materials for the preparation of *Smurfies*

Figure 3.4 Extrusion of *Smurfies*

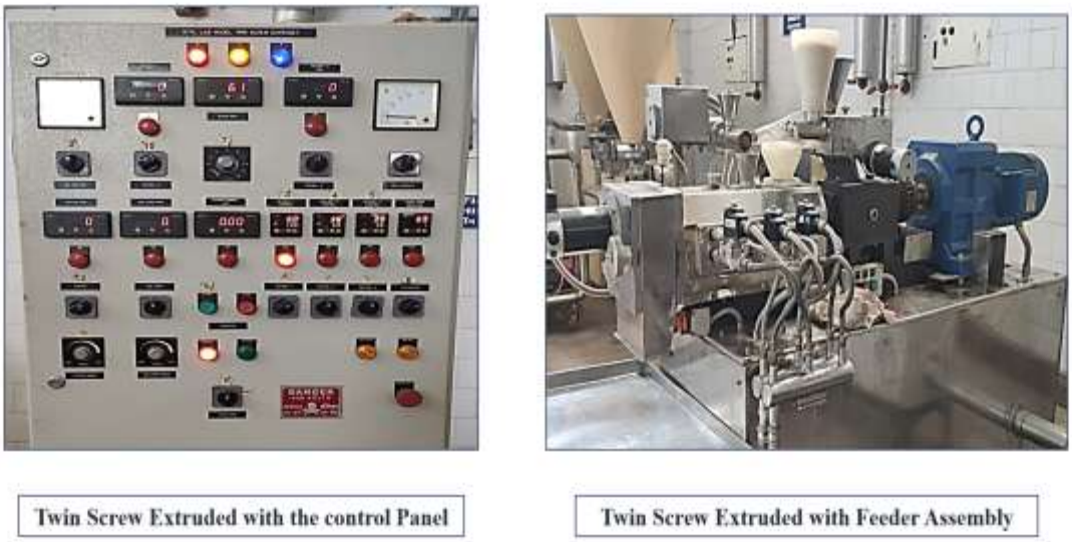

Figure 3.5 Twin Screw Extruder with Control Panel and Feeder Assembly

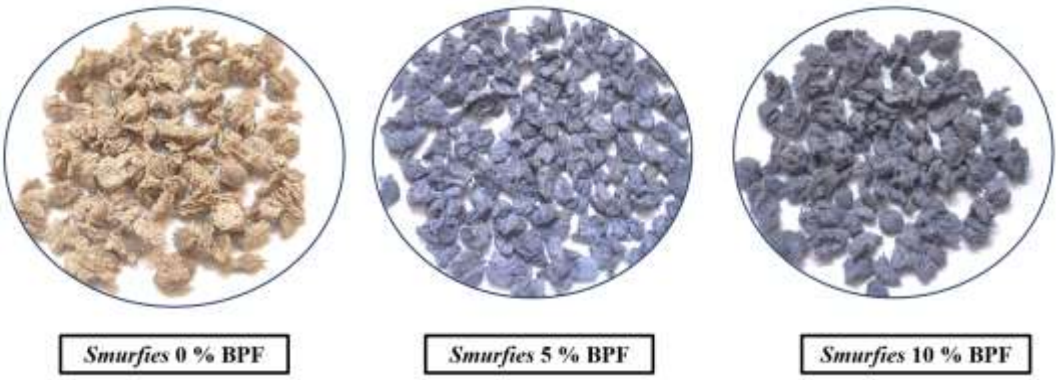

Figure 3.6 *Smurfies* at the various levels of BPF

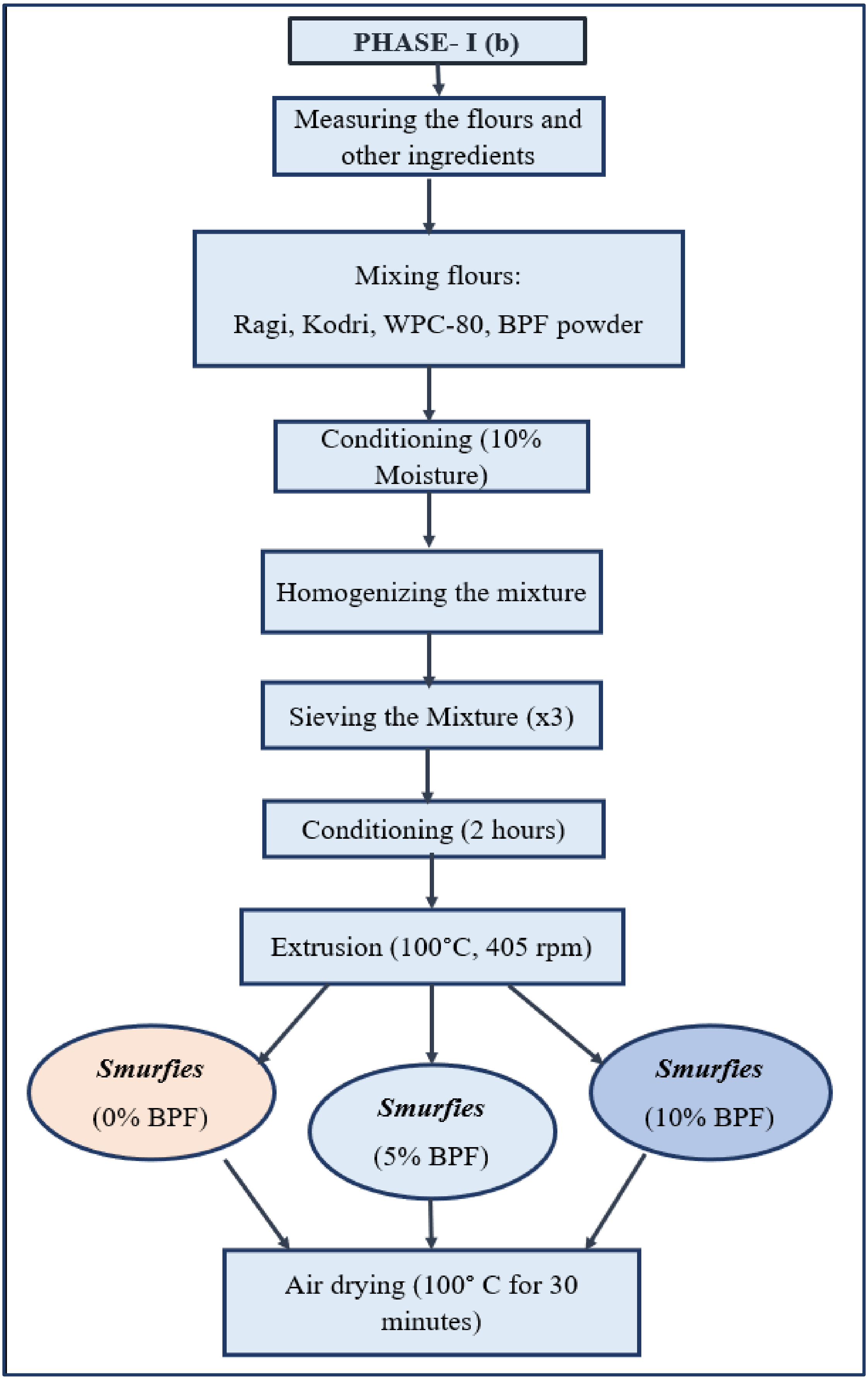

Figure 3.7 Procedure for Extrusion of *Smurfies*

Table 3.2 Tools And Techniques

Sr. No	Equipment/ Instruments used	Details
1	Analytical Balance	Sartorius England
2	Co-rotating twin screw extruder machine	BTPL Lab model, Basic Technology Pvt. Ltd. Kolkata, India
3	Hot air oven	Model No. IK-III, Make: IKON, India

PHASE II

3.2 Product Evaluation Phase

Phase II involved a comprehensive evaluation of the developed *Smurfies* to assess their quality, acceptability and functional characteristics. Proximate and antioxidant analyses were performed, while textural evaluation confirmed product consistency. Cost-effectiveness and shelf life were assessed under controlled storage conditions. Furthermore, the glycaemic index was evaluated to determine the product's suitability for health-conscious individuals and those with diabetes.

3.2.1 Comprehensive Evaluation of *Smurfies:* Chemical, Physical, Antioxidant, Microbial, Cost and Shelf-Life Analysis

A comprehensive evaluation of *Smurfies* was carried out using standard protocols to assess chemical, sensory, physical, microbial, cost and shelf-life parameters. These standardized methods ensured accurate analysis of nutritional content, consumer acceptability, texture, safety, economic viability and storage stability, thereby validating the overall quality of the developed product.

3.2.1.1 Proximate Principles analysis of the *Smurfies*

The *Smurfies* at the varying levels of BPF (0 %, 5 % and 10 %) were analysed for proximate principles at the National Institute of Food Technology Entrepreneurship and Management (NIFTEM), Kundli, Sonipat, Haryana. The parameter and the methods of the tests performed are detailed in the Table 3.3.

Table 3.3 Chemical Quality Analysis of *Smurfies*

Sr. No.	Parameter Analyzed	Method of Analysis
1.	Moisture	AOAC, 21st Edn, 2019 (George & Latimer, 2019), (Gupta & Sridevi, 2022)
2.	Protein	AOAC, 21st Edn, 2019, (George & Latimer, 2019), (Gupta & Sridevi, 2022)
3.	Ash	AOAC, 21st Edn, 2019, 923.03; Cha 32.1.05; Vol II; Pg: 2, (George & Latimer, 2019), (Gupta & Sridevi, 2022)
4.	Crude Fat	AOAC, 21st Edn, 2019, (George & Latimer, 2019), (Gupta & Sridevi, 2022)
5.	Carbohydrate	By difference method. (Menezes et al., 2004)
6.	Energy	Food Labeling – Requirements for FDA Regulated products, by James L. Vetter, E. M. Melran, Ed., AIB International. Manhattan, K.S, 2007 (Vetter & Meloan, (2007), (Gupta & Sridevi, 2022)

3.2.1.2 Antioxidant Profiling of *Smurfies*

The DPPH (2,2-diphenyl-1- picrylhydrazyl)

DPPH analysis was conducted to evaluate the antioxidant activity of *Smurfies,* supporting their functional food potential. The detailed protocol and method are provided in Annexure III. Figure 3.8 shows the preparation of DPPH assay.

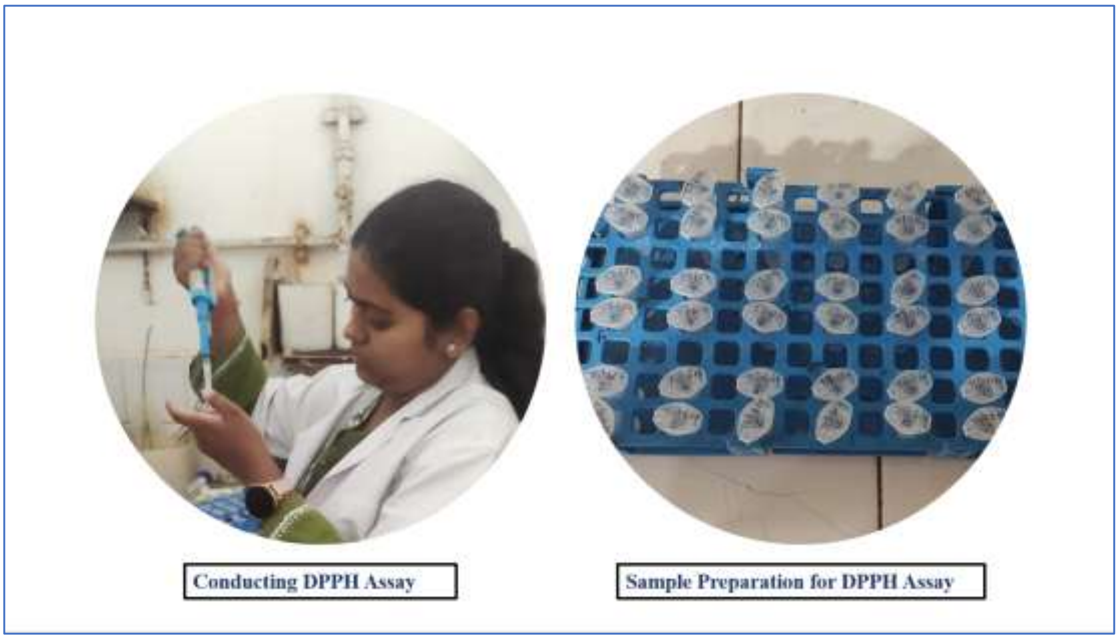

Figure 3.8 Preparation of DPPH Assay

3.2.1.3 Textural Characterization of *Smurfies*

Texture analysis of *Smurfies* for hardness and crispness was conducted at Hemshell Services LLP, located at 903/1 Makarpura GIDC Industrial Estate, Makarpura, Vadodara, Gujarat, using a Universal Testing Machine (UTM), Model LS5 (AMETEK LLOYD, USA), in compression mode with a 100 N load cell at 0.5 mm/sec speed, under controlled conditions (23°C ± 2°C, 50% ± 5% RH).

3.2.1.4 Microbiological Quality Assessment of *Smurfies*

Microbial analysis of *Smurfies* was carried out to ensure product safety and compliance with food quality standards. The evaluation included testing for water activity (in accordance with AOAC guidelines and the protocol described by Pardo et al. (2004)), yeast and mold as per IS 5403:1999 (reaffirmed in 2018), total coliforms in accordance with IS 5401 (Part 1) and Total Plate Counts (TPC) following the method outlined in IS 5402 (Part 1). These microbial studies were conducted to assess the hygienic quality of the product and its microbiological stability during storage, which are critical for consumer safety and shelf-life validation.

3.2.1.5 Accelerated Shelf-Life Assessment of *Smurfies*

Shelf life refers to the time a food product maintains acceptable quality which can be determined through microbial evaluations. Influenced by formulation, processing, packaging and storage, *Smurfies* were stored in food-grade zip-lock bags at 35 ± 2°C and 70% RH for 49 days. Accelerated Shelf-Life Testing (ASLT) was applied, with microbial quality assessed every 7 days.

3.2.1.5 Cost Estimation of *Smurfies*

The cost analysis method employed in this study involved an extensive breakdown of costs related with producing the variants of *Smurfies.* At first raw material costs were determined by considering the rates and amounts of each item used in *Smurfies.* The total yield obtained was then used to calculate the cost of *Smurfies.*

3.2.2 Evaluation of Glycaemic index of the Blue Pea flower incorporated *Smurfies*

Enrolment of Subjects

A total of 10 healthy adult male and female volunteers aged between 18–25 years were enrolled in the study based on predefined inclusion and exclusion criteria. All participants provided informed consent and were selected from the Department of Foods and Nutrition, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda. Prior to the study, anthropometric measurements and health status were assessed through a structured questionnaire (Appendix IV, V and VI).

Inclusion Criteria:

- Adults with a normal BMI (18.5–22.9 kg/m²)
- Willingness to voluntarily participate in the study

Exclusion Criteria:

- History of chronic illnesses
- Use of dietary supplements
- Known allergies to milk protein or Blue Pea Flower
- Thyroid disorders
- Pregnancy or lactation

- Unwillingness to participate

Procedure

The glycaemic index (GI) of *Smurfies* was determined using the International Organization for Standardization protocol (ISO 26642:2010). The most acceptable formulation of *Smurfies* (with optimal Blue Pea Flower incorporation) was selected for GI evaluation. Each of the 10 participants attended multiple study sessions. On the first visit, subjects consumed 50g glucose as the reference food, OGTT. On subsequent visits, participants consumed a portion of *Smurfies* with 0% BPF and another portion with the selected optimal level of BPF, each providing 50g of available carbohydrates. The schematic diagram for estimation of Glycaemic Index of *Smurfies* is shown in Figure 3.9.

Each test session included:

- Collection of fasting blood sample by a trained technician
- Consumption of the test or reference food within 15 minutes
- Blood glucose measurements via finger prick at 15, 30, 45-, 60-, 90- and 120-minutes post-consumption

Evaluation of Glycaemic Index

Participants were tested in the morning after a 10–12 hour overnight fast. Following a two-day washout period, the alternate food was tested. Blood glucose responses were plotted and the incremental area under the curve (iAUC) was calculated using the trapezoidal method, following WHO/FAO guidelines (1998). The GI was computed using the formula:

$$\text{Area of trapezoid} = \frac{(Increment_1 + Increment_2)}{2} \times (Time_2 - Time_1)$$

Statistical Analysis

Data were compiled and entered into Microsoft Excel after verification. Statistical analysis included the calculation of mean.

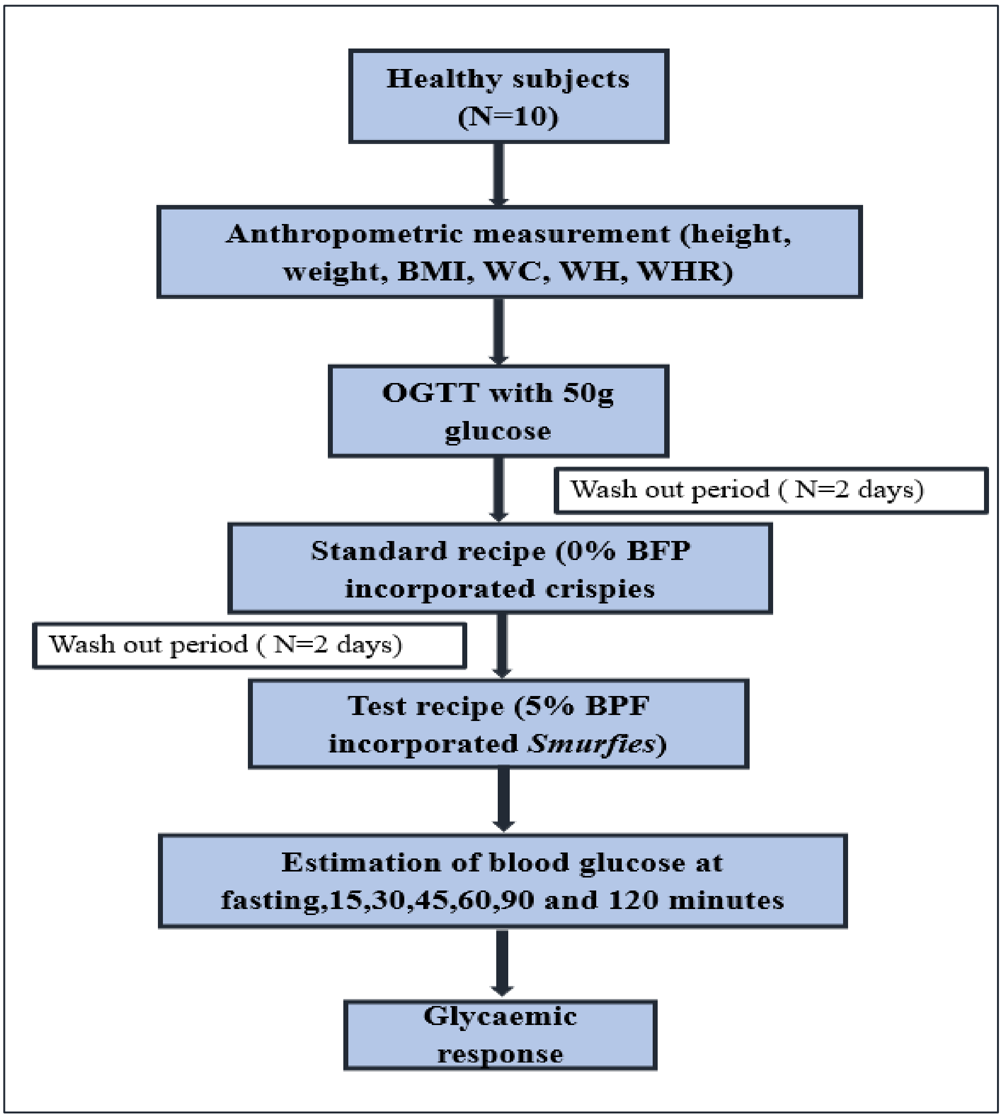

Figure 3.9 Schematic Diagram for the Estimation of Glycaemic Index of *Smurfies*

Table 3.4 Tools and Technique for Phase II (b)

Sr. No	Tools/ Instrument	Details
	For DPPH	
1	Microcentrifuge Tubes	2 ml
2	Micropipette	2-20µg
3	Micropipette	1000µg
4	Micropipette	100-1000µg
5	Micropipette tips	For Micropipette
6	DPPH	2,2 – Diphenyl- Picrylhydrazyl (DPPH) EP 250 mg
7	Methanol	Methanol EP AR 500ml

8	Falcon	To store DPPH
9	Cylindrical flask	To measure methanol
10	Samples	0%, 5% and 10% *Smurfies*
11	Hydrochloric acid	For acid hydrolysis
12	Water bath	For acid hydrolysis
For Glycaemic index		
14	Glucometer	One Touch Select Plus Simple
15	Lancets	One Touch Select Plus Simple
16	Strips	One Touch Select Plus Simple
17	Cotton balls	For wiping
18	Rubbing Alcohol	Isopropyl Rubbing Alcohol Isolite
19	Glucose and water	OGTT
20	Samples	(0% and 5% *Smurfies*)

PHASE III

3.3 Product Application Phase

In the product application phase, *Smurfies* were incorporated into the development of innovative breakfast recipes. These recipes were then evaluated through sensory assessment to determine consumer acceptability, focusing on taste, texture, appearance and overall appeal of *Smurfies* -based preparations. Post sensory evaluation, questionnaire was given to fill the details of Demographic detail (such as Name, gender, age,), breakfast cereal consumption pattern, health and nutritional perception, sustainability and Local sourcing was to analysis perception of panellist regarding *Smurfies*.

3.3.1 Development of Breakfast recipes featuring *Smurfies* as a key ingredient

Smurfies were used as a key ingredient in standardized breakfast recipes such as parfaits, smoothies, breakfast bars, muffins, breads and granolas. These recipes were developed and standardized using common kitchen tools to ensure practical applicability and consumer relevance. Sensory evaluation was conducted to assess the acceptability of these *Smurfies* -based preparations in terms of taste, texture, appearance and overall appeal. Costing of the recipes was done aiming to assess the product's potential market feasibility and pricing competitiveness.

Parfait

Parfait is a layered breakfast dish typically prepared using yogurt or cream, fruits and a crunchy element such as granola. Ingredients other than Smurfies were carefully selected to prepare high quality parfait. Cost calculation was done summing up the ingredient cost.

Table 3.5 Standardization of *Smurfies* -Based Parfait (0%, 5% and 10% BPF incorporated *Smurfies)*

Ingredients	Amount (g/ml)	Cost per 100g (□)	Cost per Serving (□)
Hung curd	150.00	115.00	17.25
Honey	5.00	65.00	3.25
Smurfies -0% BPF	30.00	100.34	30.10
Smurfies -5% BPF	30.00	115.24	34.57
Smurfies -10% BPF	30.00	130.14	39.04
Strawberries	5	20	1
Blueberries	5	160	8
Total (0% BPF)	-	460.34	52.4
Total (5% BPF)	-	475.24	56.87
Total (10% BPF)	-	490.14	61.34

Method of Preparation:

- For hung curd: Desiccate curd in a soft cotton cloth overnight or at least for 6-8 hours and let the excess water drain out.
- Once the curd is desiccated, add honey and blend until smooth creamy texture. Keep it aside or in refrigerator.
- Wash and clean the fruits and cut into small pieces.
- Take a glass or bowl, place a layer of *Smurfies* at the bottom of the glass or bowl
- Cover the layer of *Smurfies* with a layer of curd
- Cover the layer of curd with a layer of fresh fruits.
- Repeat the layers until the glass or bowl is full, keep adding *Smurfies,* curd and fruits in layers.

- Garnish the top layer with fruits

Smoothie

It is a thick blended beverage made from milk, fruits nuts and seeds and other ingredients.

Table 3.6 Standardization of *Smurfies* -Based Smoothies (0%, 5% and 10% BPF incorporated *Smurfies*)

Ingredients	Amount (g/ml)	Cost per 100g (□)	Cost per Serving (□)
Milk	120	5.6	6.72
Banana	12.5	4	0.5
Oats	25.5	49	12.49
Smurfies -0% BPF	4.5	100.34	4.51
Smurfies -5% BPF	4.5	115.24	5.18
Smurfies -10% BPF	4.5	130.14	5.8
Chia seeds	7.5	132	9.9
Honey	7.5	65	4.8
Vanilla extract	0.03	606.25	0.18
Almonds	3.00	158.5	4.75
Pistachio	3.00	160	4.8
Strawberries	5.00	20	1
Total (0% BPF)	-	1280.69	48.65
Total (5% BPF)	-	1295.59	49.32
Total (10% BPF)	-	1310.49	49.94

Method of Preparation

- In a blender add Banana, milk, oats, chia seeds, honey, vanilla extract and blend until smooth and creamy.
- Garnish with chopped almonds, pistachio and strawberry for garnishing.

Muffins

Breakfast muffins are small single- serving baked cakes. They are made from healthy ingredients and are intended to be an easy and quick breakfast choice. They are usually created with healthy grains, fruits, nuts, or proteins and are generally less sugary and more nutrient-dense than normal cupcakes.

Table 3.7 Standardization of *Smurfies* -Based Muffins (0%, 5% and 10% BPF incorporated *Smurfies*)

Ingredients	Amount (g/ml)	Cost per 100g (□)	Cost per Serving (□)
Whole wheat flour	28.33	5.26	1.4
Smurfies -0% BPF	1.6	100.34	1.6
Smurfies -5% BPF	1.6	115.24	1.84
Smurfies -10% BPF	1.6	130.14	2.08
Blueberries	1.6	299	4.78
Baking powder	0.41	33	0.13
Baking soda	0.10	30	0.03
Sugar	12.5	4.8	0.6
Milk	20	56	11.2
Lemon juice	1.25	20	0.25
Oil	5	19	0.95
Vanilla essence	0.03	606.25	0.18
Total (0% BPF)	-	1173.65	21.12
Total (5% BPF)	-	1188.55	21.36
Total (10% BPF)	-	1203.45	21.6

Method of Preparation

- Grease the muffin tray gently and line it with paper liners. Preheat the oven at 375°F, or 190°C
- In a large bowl, combine all the dry ingredients and whisk thoroughly.
- In another large bowl, combine all the wet ingredients and mix well.

- Combine all the dry and wet mixtures until they are just combined. The batter should be a little lumpy; avoid overmixing.
- Add the mix-ins blueberries and fold them in.
- To fill the muffin cups, use a spoon, fill each muffin tin cup about two-thirds of the way to the top.
- Bake for 18 – 22 minutes, or until a toothpick inserted in the centre comes out clean, in a preheated oven.
- After 5 minutes of cooling in the muffin tray, transfer the muffins to a wire rack.

Bread

Bread is a cereal-based food made from flours, water and yeast or another leavening agent. It is baked. It is a key part of many cuisines worldwide. It can be eaten on its own, used for sandwiches, served in breakfast or as a side with meals.

Table 3.8 Standardization of *Smurfies* -Based Bread (0%, 5% and 10% BPF incorporated *Smurfies*)

Ingredients	Amount (g/ml)	Cost per 100g (□)	Cost per Serving (□)
Whole wheat flour	330	6.18	20.39
Sugar	15	4.8	0.72
Yeast	15	160	6
Water	120		
Smurfies -0% BPF	30	100.34	30.10
Smurfies -5% BPF	30	115.24	34.57
Smurfies -10% BPF	30	130.14	39.04
Total (0% BPF)	-	271.32	57.21
Total (5% BPF)	-	286.22	61.68
Total (10% BPF)	-	301.12	66.15

Method of Preparation

- Activation of Yeast: In a bowl, add water, sugar and yeast and mix well. Let it settle for 5–10 minutes till it becomes foamy.
- Mixing of Dough: In a large bowl, add flours, *Smurfies* and salt, mix everything well. Transfer the activated yeast mixture along with oil in the large bowl. Stir everything thoroughly till it combines and forms a sticky dough.
- Kneading of the Dough: Sprinkle some flour and transfer the dough to a floured surface and knead for about 10 minutes until it becomes elastic and smooth.
- Proofing (First rise): Grease a bowl and place the kneaded dough into it, cover with a damp cloth and let it rise in a warm place for about 1–2 hours until its size doubles.
- Shaping the Dough: To release the air, punch down the dough. Knead and shape the dough into a loaf shape.
- Second Rise: Grease the loaf tray and place the shaped dough into it. Cover it and let it rise again for about 30–45 minutes till it becomes slightly puffy.
- Baking the Bread: Preheat the oven at 375°F (190°C). Bake for 25–30 minutes or until the bread is golden brown and sounds hollow when tapped.
- Cool down: Remove the tray from the oven and let the bread cool down on a wire rack. Once the bread is completely cooled down, cut into slices.

Granolas

Granola is a crunchy baked blend of oats, nuts, seeds, honey/maple syrup and dried fruit. It is a nutrient dense snack and is frequently used as a snack, as a cereal for breakfast with milk or yogurt, or as a garnish for desserts and smoothie bowls.

Table 3.9 Standardization of *Smurfies* -Based Granolas (0%, 5% and 10% BPF incorporated *Smurfies*)

Ingredients	Amount (g/ml)	Cost per 100g (□)	Cost per Serving (□)
Rolled oats	37	49	18.13
Honey	3	65	19.5
Jaggery powder	5	24	1.2
Oil	3	19	0.57
Almonds	4	158.5	6.34

Pumpkin seeds	2	124	2.48
Sunflower seeds	2	74.5	1.49
Chia seeds	2	132	2.64
Dried fruits:			
• ***Black raisins***	4	62	2.48
• ***Cranberries***	4	149	5.96
Vanilla extract	0.03	606.25	0.18
Smurfies -0% BPF	30	100.34	30.10
Smurfies -5% BPF	30	115.24	34.57
Smurfies -10% BPF	30	130.14	39.04
Total (0% BPF)	-	1563.59	91.07
Total (5% BPF)	-	1578.49	95.54
Total (10% BPF)	-	1593.39	156.33

Method of Preparation

- Preheat the oven at 325°F (163°C) and put parchment paper on a baking pan.
- In a large bowl, combine rolled oats, jaggery powder, honey, oil, pinch of cinnamon and vanilla essence. Mix everything well.
- Spread the mixture on a baking sheet and evenly distribute the mixture everywhere on the baking tray.
- Bake the mixture for 20-25 minutes, till the granola turns brown also stir once in between.
- Once done, take out the tray from the oven and let it cool down completely on a baking sheet it becomes crisp.
- Slice the almonds and roughly chop the dried fruits.
- Once the granola mixture cools down completely and tuns crisp, transfer it into the storing container. Add the *Smurfies,* also add the sliced almonds, chopped dried fruits, pumpkin seeds, sunflower seeds and chia seeds. Mix everything well.
- Store and keep it in an airtight container at room temperature.

Breakfast Bars

Breakfast bars are nutrient-dense, portable and compact snack bars that are meant to be consumed as a quick, easy and time-saving breakfast. A variety of grains, nuts, seeds, dried fruits and some amounts of sweeteners are used to make them.

Table 3.10 Standardization of *Smurfies* -Based Breakfast Bars (0%, 5% and 10% BPF incorporated *Smurfies*)

Ingredients	Amount (g/ml)	Cost per 100g (□)	Cost per Serving (□)
Oats	120	49	58.8
Smurfies -0% BPF	30	100.34	30.1
Smurfies -5% BPF	30	115.24	34.57
Smurfies -10% BPF	30	130.14	39.04
Almonds	10	158.5	15.88
Dates	120	57.8	69.36
Seeds:			
• *pumpkin seeds*	5	124	6.2
• *sunflower seeds*	5	74.5	3.72
Choco chips	5	152	7.6
Black raisins	5	62	3.1
Cranberries	5	149	7.45
Vanilla essence	0.03	606.25	0.18
Jaggery powder	125	24	30
Total (0% BPF)		1557.39	232.39
Total (5% BPF)		1572.29	236.86
Total (10% BPF)		1587.19	241.33

Method of Preparation

- In a saucepan, add jaggery powder and dates over a low flame until they melt and combine.
- Turn of the flame, add a pinch of cinnamon and vanilla essence.
- Add all the dry ingredient- oats, *Smurfies* powder, seeds, Choco chips, black raisins, cranberries and almonds.

- Mix everything well until all the ingredients are evenly covered.
- Put parchment paper in a baking tray.
- Transfer all the mixture into the baking tray. Spread the mixture evenly in the tray and firmly press at all sides with hand s or spatula.
- Bake the bars at 160° C for 20-25 minutes.

3.3.2 Sensory Assessment of *Smurfies* -Based Breakfast Recipes

The breakfast recipes developed were subjected to a sensory evaluation in order to determine:

- Whether *Smurfies* could be successfully incorporated into them,
- Assess the dishes' acceptability and
- Track any changes in various sensory qualities that might occur when *Smurfies* are included.

Using a 9-point Hedonic rating scale and a composite rating scale, a semi-trained panel of 30 to 35 people who voluntarily consented to participate in the study (based on the inclusion and exclusion criteria) conducted a sensory evaluation of the breakfast recipes (appendix VI) and then followed by a semi- structured questionnaire seeking details on Demographics, health and Nutritional perception and Sustainability and Local sourcing (appendix VII).

Inclusion criteria:

- Semi-trained panel members who have provided informed consent to participate
- Individuals with sound health

Exclusion criteria:

- Individuals who decline participation
- Individuals having allergy to any of the components of the *Smurfies*

9- Point Hedonic Scale-

The 9-point hedonic scale, is the most commonly used rating scale for determining food acceptability, often known as the degree of liking scale. It has nine rating points from "like extremely" to "dislike extremely," with "neither like nor dislike" acting as the mid-point (appendix VIII).

Composite rating scale-

The composite rating test's objective is to evaluate each product's unique features. This approach makes it simpler to compare and grade quality aspects by highlighting specific attributes that are unsatisfactory. The total of each attribute's scores is then analysed and compared across the many product iterations. Sensory evaluation of the developed crispies with 0%, 5% and 10% Blue Pea Flower (BPF) incorporation was conducted to identify the most acceptable level for further analysis. A semi-trained panel comprising 30–35 members from the Department of Foods and Nutrition, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, who voluntarily provided informed consent participated in the study. The coded samples of each variant were presented to panellists for unbiased assessment using a composite rating scale. This scale was designed to evaluate specific sensory attributes and identify any undesirable characteristics, enabling effective comparison across variants. The attributes assessed included colour and appearance, flavour, taste, texture, mouthfeel, aftertaste and overall acceptability. The total sensory score was calculated by summing the scores of all attributes, which was then used to compare and rank the different formulations of the *Smurfies* incorporated recipes (appendix IX).

Statistical analysis

The data was verified and subjected to statistical analysis using Microsoft Excel. Appropriate segregation of the data was done and following calculations were performed to formulate desired results:

- Mean and standard deviation,

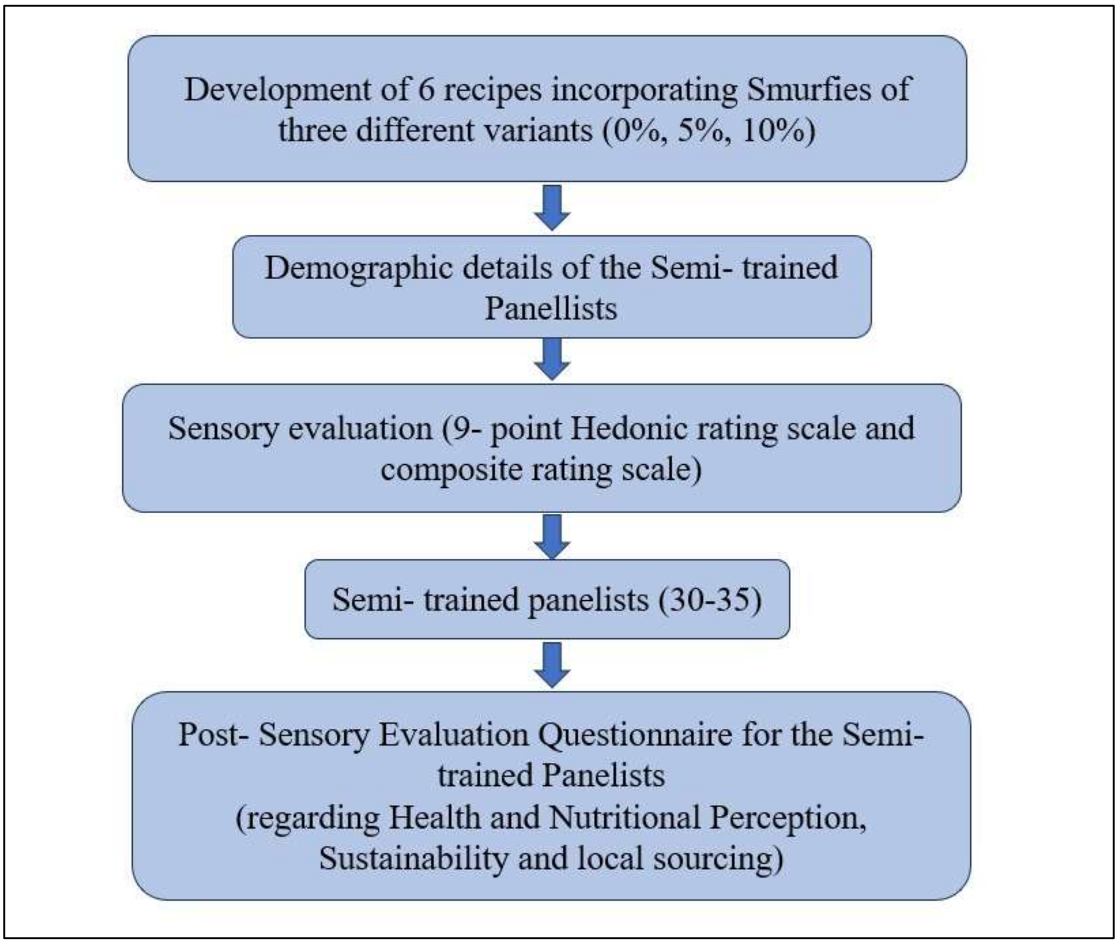

Figure 3.10 Experimental Design for Sensory Evaluation

The tools and techniques used in the phase is as shown in the Figure 3.11

Table 3.11 Tools And Techniques

Sr. No	Parameters	Details
1	Kitchen tools	For Standardization of Recipes
2	Analytical weighing machine	For measuring raw ingredients
3	Sensory attributes	9- point Hedonic Rating Scale
4	Sensory attributes	Composite Rating Scale
5	Post- Sensory Evaluation survey	Pre- tested Questionnaire

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

The Results and Discussion section is one of the significant aspects for any thesis, dissertation or research paper. It summarizes the study's outcomes and explains their significance in light of the goals of the investigation. The data gathered from surveys, experiments, or studies is presented here, it contains statistical results, tables and graphs. It helps to present the results objectively so that readers may comprehend and draw conclusions from it. This section explicates and analyses the results.

The research findings presented in this chapter stem from a systematically designed and well-executed methodological framework that minimized bias and experimental error, thereby enhancing the reliability and validity of the results. The study, titled *"Development and Characterization of Smurfies: A Blue Pea Flower (Clitoria ternatea) Powder Enriched Extruded Millet and Milk Protein-based Breakfast Cereal"*, aimed to develop a functional extruded breakfast cereal enriched with Blue Pea flower, millets and milk protein. The formulation and evaluation of the product—termed *Smurfies*—were guided by insights from a preliminary market survey and further assessed through comprehensive chemical, physical, sensory, microbial, cost and shelf-life analyses, along with a glycaemic index study. Additionally, various breakfast recipes incorporating *Smurfies* were developed and evaluated for consumer acceptability. The outcomes discussed in this chapter provide insight into the nutritional, functional and sensory performance of the product, reflecting its potential as a health-oriented cereal option.

The study was carried out in the following three phases:

PHASE- I (a). Market survey:

1. To identify and analyse existing and similar breakfast cereal products
2. To compare the ingredient composition of available breakfast cereals
3. To evaluate the nutrient composition of existing breakfast cereals
4. To analyse the cost structure of existing products

PHASE I (b). Development of Blue Pea incorporated *Smurfies:*

1. To choose appropriate components, including the types of millet, milk protein and Blue Pea Flower (*Clitoria ternatea*) for creating *Smurfies*
2. To obtain high-quality ingredients that meet the formulation requirements for the cereal
3. To develop a cohesive extruded product by combining millet and milk protein, incorporating Blue Pea Flower (BPF) at three varying levels, utilizing extrusion process technology.

PHASE II (a). Chemical, organoleptic, physical, microbial, cost analysis and shelf-life study of the *Smurfies:*

1. To analyse the chemical composition and antioxidant profile of *Smurfies* (proximate principles)
2. To assess textural properties
3. To perform a cost analysis
4. To evaluate the shelf life under storage conditions

PHASE II (b). Glycaemic index study of the *Smurfies:*

1. To determine the glycaemic index of the BPF incorporated millet and milk-protein based *Smurfies*

PHASE III (a). Create breakfast recipes featuring *Smurfies* as a key ingredient:

1. To develop breakfast recipes incorporating *Smurfies* as a key ingredient

PHASE III (b). Conducting sensory evaluation of the developed recipes:

1. To evaluate the sensory attributes (taste, texture, appearance and overall acceptability) of the developed recipes
2. To assess consumer preference and acceptability of the *Smurfies* -based breakfast recipes through sensory evaluation trials

The results of the study are discussed below:

4.1 Market Survey and Product Development Phase

4.1.1 Market Survey of Commercial Breakfast Cereal Products

4.1.2.1 Concept Generation, Screening and Prototype Development

4.1.2.2 Selection of suitable components for the development of *Smurfies*

4.1.2.3 Proximate Analysis of Raw Materials

4.1.2.4 Formulation and Standardization of *Smurfies* with Varying Levels of Blue Pea Flower

4.2 Product Evaluation Phase

4.2.1 Comprehensive Evaluation of *Smurfies:* Chemical, Physical, Microbial, Cost and Shelf-Life Analysis

4.2.1.1 Proximate Principles analysis of the *Smurfies*

4.2.1.2 Antioxidant Profiling of *Smurfies*

4.2.1.3 Textural Characterization of *Smurfies*

4.2.1.4 Microbiological Quality Assessment of *Smurfies*

4.2.1.5 Accelerated Shelf-Life Assessment of *Smurfies*

4.2.1.6 Cost Estimation of *Smurfies*

4.2.2 Evaluation of Glycaemic index of the Blue Pea flower incorporated *Smurfies*

4.3 Product Application Phase

4.3.1 Development of Breakfast recipes featuring *Smurfies* as a key ingredient

4.3.2 Sensory Assessment of *Smurfies* -Based Breakfast Recipes

4.1 Market Survey and Product Development Phase

4.1.1 Market Survey of Commercial Breakfast Cereal Products

In Phase I of the study, a comprehensive market survey was conducted to identify and analyze existing breakfast cereal products available in the market. A total of 45 breakfast cereal products representing 12 different brands were examined. The analysis was carried out based on six key criteria: the ingredients used in the products, their net weight, cost, recommended serving size, nutritional value and shelf life. This survey provided valuable insights into the current trends, composition and market positioning of commercially available breakfast cereals, serving as a foundational step for the development of a novel product in the subsequent phases of the study. The growing consumer demand for quick and healthful breakfast cereals is driving significant expansion in the breakfast cereals sector. People who value their health tend to favour breakfast cereals like granolas and muesli. To learn more about the market environment, a thorough market survey was conducted. The study primarily looked at the market's breakfast cereals' availability, variety and key features. A wide range of domestic and foreign products that were exclusively accessible to Indian consumers in both online and offline markets were included in the study.

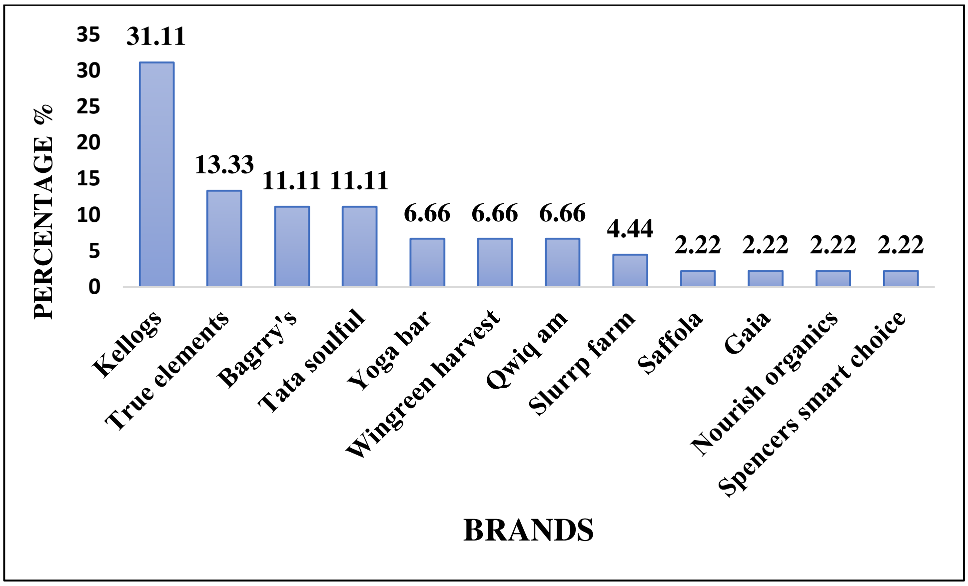

Figure 4.1 Breakfast Cereal Brands Overview

Figure 4.1 presents the distribution of 45 breakfast cereal products across 12 brands surveyed during Phase I of the study. Among these, Kellogg's emerged as the dominant brand, accounting for 31.11% of the total products assessed. This highlights its strong market presence and widespread consumer acceptance. True Elements followed with a 13.33% share, suggesting a significant, though more niche, foothold in the market. Bagrry's and Tata Soulful each represented 11.11% of the surveyed products, indicating their competitive stance in the breakfast cereal segment. Brands such as Yoga Bar, Wingreens Harvest and Qwik am held 6.66% each, reflecting moderate visibility in the market. Meanwhile, Slurrp Farm had a 4.44% share and lesser-represented brands like Saffola, Gaia, Nourish Organics and Spencer's Smart Choice each accounted for only 2.22% of the market.

This brand-wise distribution suggests that the market is dominated by a few large players, with several emerging and niche brands beginning to carve out their space. The presence of multiple brands also reflects the diversity in product offerings and potential opportunities for innovation in the breakfast cereal segment. The following figures further explore the ingredient composition trends among these products, offering insights into commonly used components that influence formulation decisions.

4.1.1.1 Ingredients Composition of Breakfast Cereals

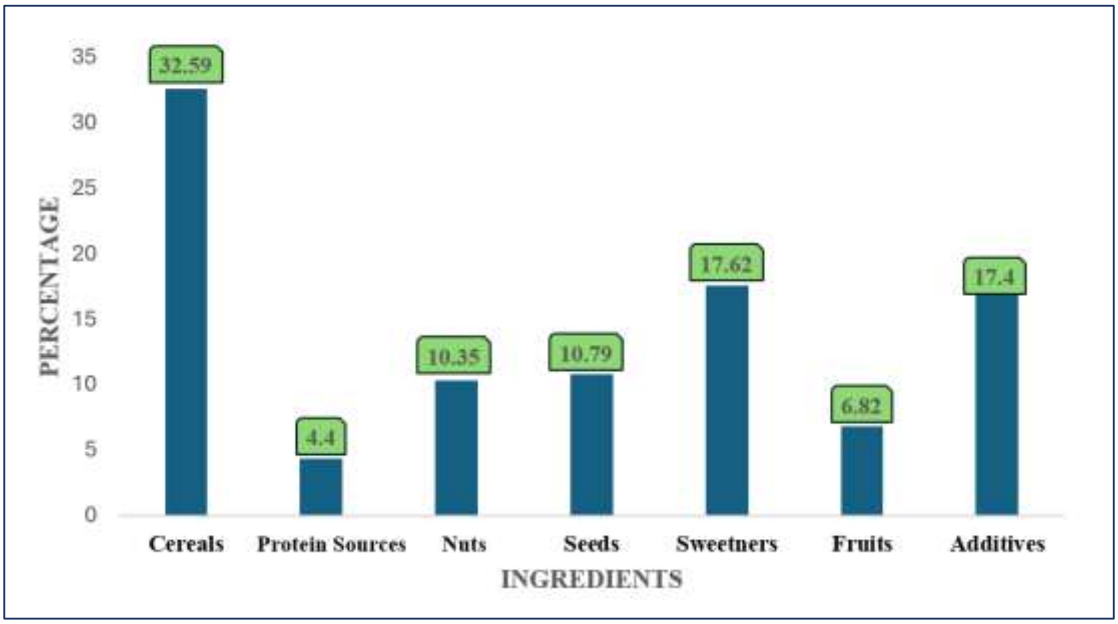

Figure 4.2 Major Ingredients Composition used in Breakfast Cereals

Figure 4.2 illustrates the ingredient composition observed on the labels of 45 breakfast cereal products. Cereals were the most commonly listed ingredient, present in 32.59% of the products, highlighting their foundational role in breakfast cereal formulations. Sweeteners (17.62%) and additives (17.4%) were the next most frequent components, indicating a strong emphasis on enhancing taste, shelf life and product appeal. Seeds (10.79%) and nuts (10.35%) were moderately used, reflecting attempts to enrich products with healthy fats, proteins and micronutrients. Surprisingly, protein-based ingredients were present in only 4.4% of the surveyed items, suggesting limited offerings of high-protein cereals in the current market. Fruits appeared in just 6.82% of the products, possibly due to challenges in processing and cost, despite their shelf life.

This analysis indicates that while most products focus on cereals and flavour-enhancing ingredients, there is considerable scope for innovation through the incorporation of natural proteins, fruits and functional components. These findings helped inform the selection of ingredients in the current study, aiming to develop a nutritionally superior and appealing breakfast cereal product that addresses existing gaps in the market.

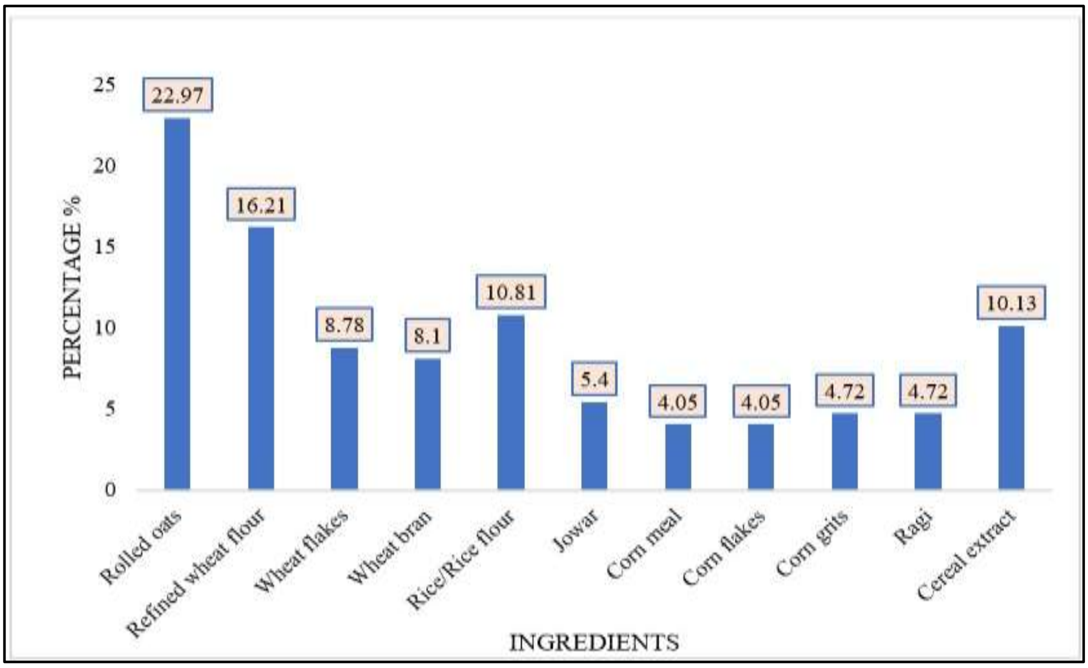

Figure 4.3 Most Common Ingredients of Cereals Category among the Surveyed Products

Figures 4.3 to 4.10 present a details breakdown of the individual ingredient compositions most commonly incorporated in the formulation of breakfast cereal products.

Figure 4.3 showed that rolled oats (22.97%) and refined wheat flour (16.21%) were the most frequently used cereal ingredients in marketed breakfast cereals. Other notable ingredients included rice/rice flour (10.81%), cereal extract (malt extract or corn syrup solids, etc) (10.13%), wheat flakes (8.78%) and wheat bran (8.1%). Less commonly used cereals were jowar, corn derivatives and ragi with 5.4 %, 4.05% and 4.72% respectively only, indicating limited incorporation of traditional and wholegrain options in commercial formulations.

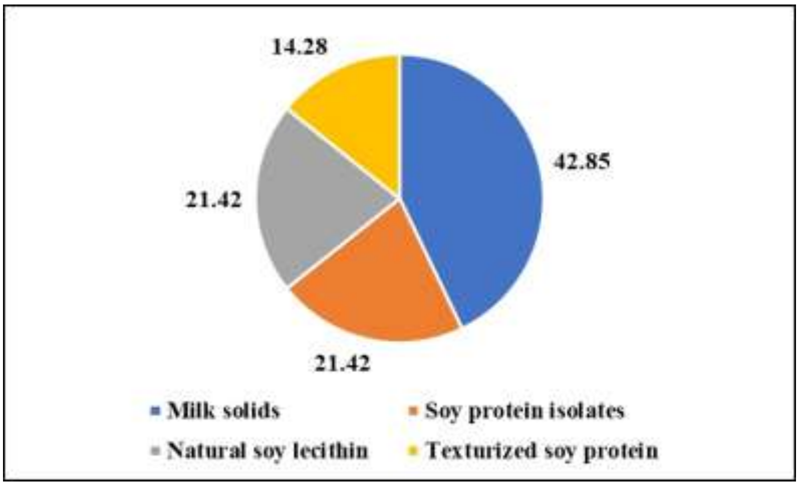

Figure 4.4 Most Common Ingredients from Protein Sources among the Surveyed Products

Figure 4.4 showed that milk solids were the most prevalent protein ingredient, used in 42.85% of the breakfast cereals. Soy protein isolates and natural soy lecithin followed equally at 21.42% each, while texturized soy protein was used less frequently (14.28%). This indicated a preference for dairy-based proteins, with soy derivatives moderately incorporated to enhance the nutritional profile and stability of products.

The Figure 4.5 below showed that almonds were the most frequently incorporated ingredient, appearing in 65.95% of the breakfast cereals. Black raisins followed at 23.4%, with raisins (10.63%) and dates (6.12%) included to a lesser extent. This suggested a strong preference for almonds due to their texture and nutritional benefits, while raisins and dates were used primarily for natural sweetness, fiber content and enhanced consumer appeal through taste and variety.

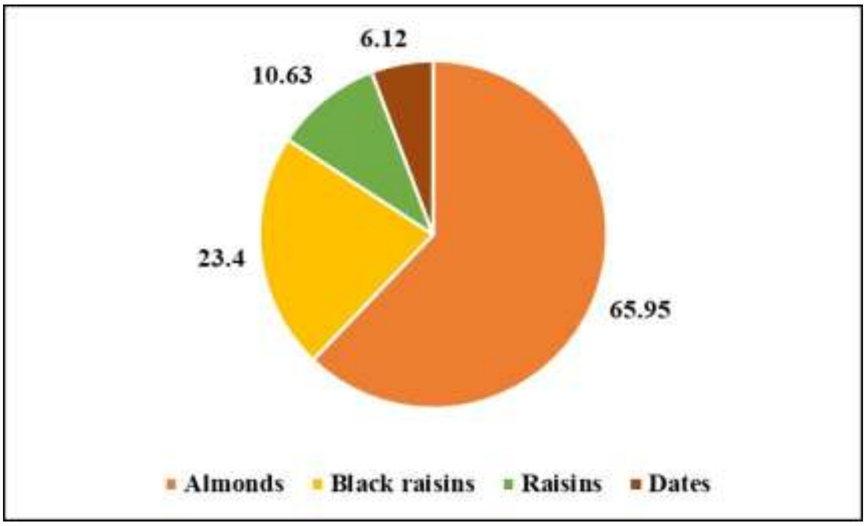

Figure 4.5 Survey-Based Distribution of Commonly Used Nuts Ingredients

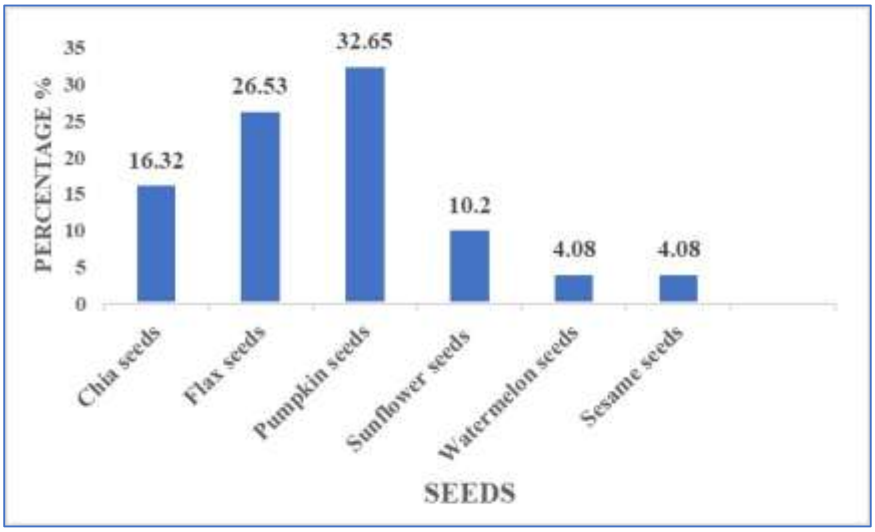

Figure 4.6 Survey-Based Distribution of Commonly Used Seed Ingredients

Figure 4.6 showed that pumpkin seeds (32.65%) were the most commonly incorporated seed ingredient in breakfast cereals, followed by flax seeds (26.53%) and chia seeds (16.32%). Sunflower seeds (10.2%), watermelon seeds (4.08%) and sesame seeds (4.08%) were used less often.

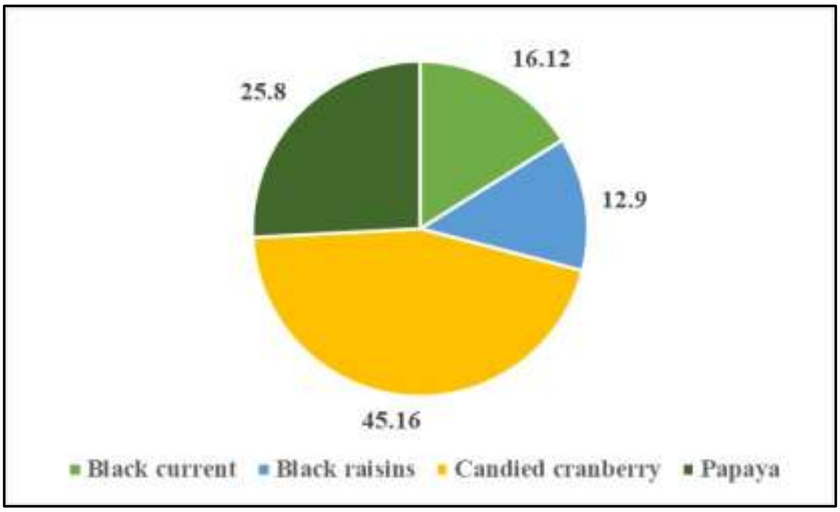

Figure 4.7 Survey-Based Distribution of Commonly Used Fruit Ingredients

Figure 4.7 illustrated that candied cranberry was the most commonly used fruit ingredient in breakfast cereals, present in 45.16% of the products. This was followed by papaya (25.8%), black currant (16.12%) and black raisins (12.9%). The data indicated a preference for sweetened, dried fruits to enhance taste, colour and shelf life, while also adding a source of natural antioxidants and dietary fiber to the cereal formulations.

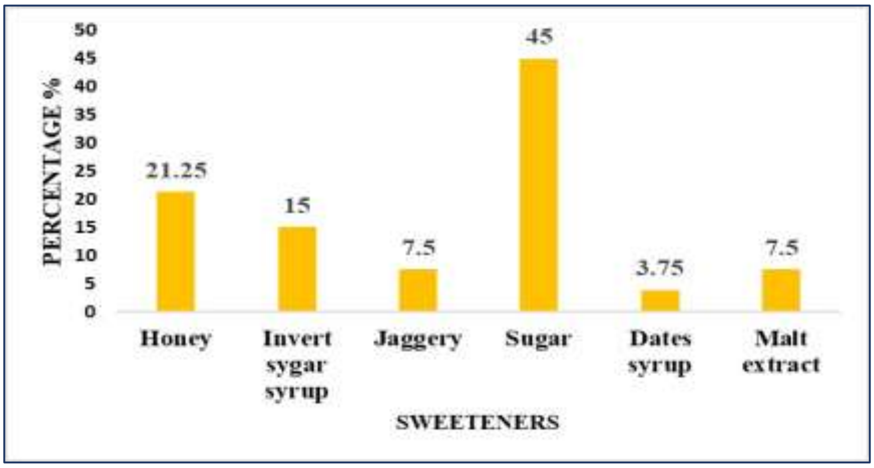

Figure 4.8 Major Sweeteners used in the Surveyed Products

Figure 4.8 illustrated the types of sweeteners commonly used in breakfast cereals. Sugar was the most prevalent sweetening agent, found in 45% of the products, highlighting its continued dominance in processed food for its affordability, sweetness intensity and preservative properties. Honey was the second most used sweetener (21.25%), likely due to its natural origin and perceived health benefits. Invert sugar syrup (15%) also featured prominently, valued for its moisture-retention and improved mouthfeel in cereals.

Less frequently used sweeteners included jaggery (7.5%), malt extract (7.5%) and dates syrup (3.75%). Cereal extracts mentioned in the product labels also indicated the use of malt and corn sugars (4.1.2.2). These ingredients, although used minimally, indicated efforts by some manufacturers to incorporate more traditional or natural sweeteners. The data reflected a growing but limited inclination toward diversifying sweetener sources in cereal formulations.

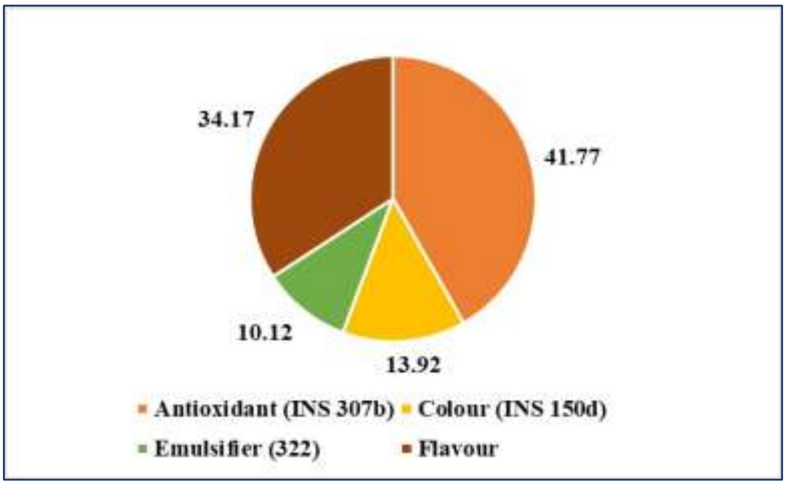

Figure 4.9 Major Additives used in the Surveyed Products

As illustrated in Figure 4.9, antioxidants (INS 307b), primarily comprising mixed tocopherols, were the most commonly used additives in breakfast cereals. These are added to enhance product stability and prolong shelf life. Flavours, both natural and artificial, followed in frequency and were used to improve the sensory appeal of the products. A relatively smaller proportion of products contained colouring agents (INS 150d, such as Sulphite Ammonia Caramel) to impart the desired visual appearance. Emulsifiers (INS 322), though used less frequently, played a key role as stabilizing agents in the final product formulation.

Figure 4.10 below shows the distribution of different millets used in breakfast cereals. Jowar was the most commonly incorporated millet, used in 51.35% of the products, followed by ragi at 37.83%. This reflects the popularity of these two millets due to their nutritional richness, gluten-free nature and consumer familiarity. In contrast, bajra (8.1%) and samai (2.7%) were used less frequently, suggesting limited market penetration or consumer acceptance despite their potential as nutrient-dense and sustainable grain options.

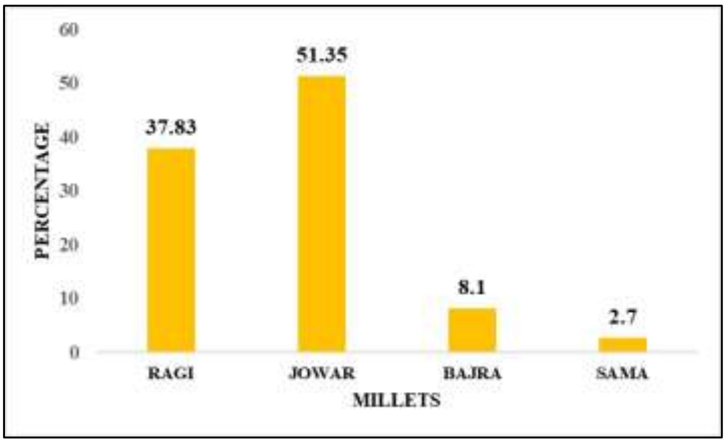

Figure 4.10 Survey-Based Distribution of Commonly Used Millets Ingredients

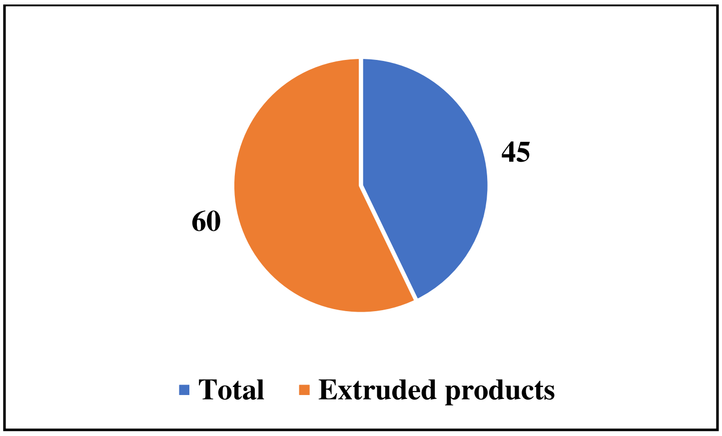

Figure 4.11 Percentage of Extruded products out of total products

The pie chart illustrates the proportion of extruded products in relation to the total samples analysed. Of the total, 60% comprised extruded products, while the remaining 45% were non-extruded. This highlights a higher preference or focus on extrusion-based formulations in the study, emphasizing its relevance in cereal product development.

4.1.1.2 Nutrient Composition of the Surveyed Breakfast Cereals

Table 4.1 presents the mean nutritional composition of breakfast cereals *analysed* in the survey. On average, the products provided 388.7 kcal, with 10.08 g of protein and 69.57 g of carbohydrates, suggesting their primary role as energy-dense foods. The fat content was moderate (8.03 g), with a relatively low proportion of saturated fats (2.04 g) and absence of trans fats, indicating a healthier lipid profile. However, the high energy from fats (46.1 g) and large standard deviation signal inconsistency among products.

The cereals offered an average of 6.73 g of dietary fiber, which is beneficial, but there's scope for improvement. Sodium content was notably high (184.97 mg), which may raise health concerns. Vitamin and mineral levels were present in varying amounts, though many were low, especially vitamin B12 and folate. Of concern, total sugars (16.96 g) and added sugars (10.79 g) were relatively high, highlighting the need for reformulation to lower sugar levels and enhance micronutrient density for better health outcomes.

The analysis of breakfast cereals Table 4.1 revealed considerable variation in their nutritional composition, highlighting differences in energy, protein, carbohydrates and fat content. Energy values ranged from 123 kcal/100g in Kellogg's Cornflakes Original to 497.5 kcal/100g in Wingreen Harvest, with a mean of 388.7 ± 63.47 (Mean± SD) kcal, indicating both low- and high-energy options catering to varied consumer needs. Protein content varied widely, from 1.9 g/100g in Kellogg's Cornflakes to 24.7 g/100g in True Elements 24g Protein Super Muesli, with an average of 10.08 ± 4.28 g, demonstrating that while most cereals provide moderate protein, select varieties are formulated for high-protein diets. Carbohydrate content, essential for energy, ranged from 24 g/100g in Qwiq AM Granolas to 69.7 g/100g in Kellogg's Cornflakes Original, averaging 69.57 ± 16.25 g. This range suggests cereals can be chosen based on desired carbohydrate intake, from low-carb to high-energy sources. Total fat content showed a broad span from 1 g/100g in Cornflakes to 24.1 g/100g in Wingreen Harvest Toasted Millet Muesli, with an average of 8.03 ± 5.61 g. The widespread allows consumers to align choices with low-fat or high-fat dietary patterns. Additionally, total sugars and added sugars averaged 16.96 ± 9.03 g and 10.79 ± 8.97 g per 100g. Breakfast cereals vary significantly in nutrient content, enabling tailored selections based on individual health goals, preferences, or dietary restrictions.

Table 4.1 Mean Nutritional Values Per 100g

Nutrients	Values (per 100g)
Energy (kcal)	388± 63
Energy from fats (g)	46.1± 53.74
Protein (g)	10.08± 4.28
Carbohydrates (g)	69.57± 16.25
Total Fats (g)	8.03± 5.61
Saturated fats (g)	2.04± 2.22
MUFA (g)	3.51± 2.87
PUFA (g)	2.52±1.73
Dietary Fibres (g)	6.73± 2.69
Sodium (mg)	184.97±143.73
Vit C (mg)	27.87±32.19
Vit B1 (mg)	0.6±0.26
Vit B2 (mg)	0.67±0.28
Vit B3 (mg)	7.45±3.60
Vit B6 (mg)	1.34±0.92
vit B12 (ug)	0.25±0.09
Folate (ug)	54.54±21.21
Iron (mg)	7.76± 4.57
Calcium (mg)	206.34±201.85
Zinc (mg)	9.6±7.51
Total sugars (g)	16.96±9.03
Added sugar (g)	10.79±8.97
Trans fats (g)	0

Table 4.2 Protein Content, Net Weight, Cost, Serving Size and Shelf-Life of Surveyed Breakfast Cereals

Protein content	Low protein (<10g)	Moderate protein (10-19g)	High protein (>20g)
Number of products (N=45)	29	13	3
Net weight (g) Mean± SD	449.82±190.69	985.38±37.71	1033.33±57.73
Cost (per 100g of Net weight) Mean± SD	63.59±11.10	80.15±2.55	111.32±14.81
Serving size Mean± SD	32.96±6.15	44.61±5.18	50± 0
Average protein per serving Mean± SD	7.88±1.81	12.07±1.14	22.73±2.23
Shelf life Mean± SD	8.82±0.38	9± 0	9.66±1.15

Table 4.2 summarizes data on various breakfast cereals categorized by their protein content, serving size, cost and shelf life. Three cereals were classified as high protein, averaging 22.73 ± 2.23g protein per serving, with individual values ranging from 1.9g to 24.7g. These high-protein options also had the highest average cost at Rs. 111.32 ± 14.81 per serving, reflecting a premium for protein content. Thirteen cereals fell into the moderate protein category, averaging 12.07 ±1.14g protein per serving and costing Rs. 80.15±2.55, making them a balanced choice between protein intake and cost effectiveness. Meanwhile, 29 cereals were classified as low protein, averaging 7.88±0.38g protein per serving and costing Rs. 63.59±1.10, despite their lower protein content.

The analysis of packaged breakfast cereals revealed considerable variation in product weight, pricing and nutritional value. Products were available in net weights ranging from 40 g to 1100 g, with an average weight of 643.44 g. Most products were sold in packs exceeding 500 g. Prices ranged from Rs. 30 to Rs. 825, with an average cost of Rs. 74.80 ± 19.47 per 100 grams. The average serving size was 37.20 grams and the average shelf life was approximately 8.98 months. These findings highlight the balance between cost, protein content and portion size key factors that influence consumer preferences and purchasing decisions based on individual nutritional goals and budget considerations.

4.1.2.1 Concept Generation, Screening and Prototype Development

The product development phase began with concept generation, followed by screening based on feasibility, cost, and nutrition. A millet, milk protein, and blue pea flower prototype was developed and tested for texture, appearance, and sensory attributes to finalize *Smurfies*.

4.1.2.2 Selection of suitable components for the development of *Smurfies*

A preliminary market survey was conducted to source high-quality ingredients, including millets, lyophilized blue pea flower (BPF), and whey protein concentrate (WPC). Premium (*Eleusine coracana*) and Kodri (*Paspalum scrobiculatum*) were procured from Miltop online, WPC-80 from NAKPRO Nutrition, and Blue Pea Flower (*Clitoria ternatea*) from 'Online of Quality Store' (Butterfly Pea Flower Herbal Tea).

4.1.2.3 Proximate Analysis of Raw Materials

The macronutrient content of the samples was examined. The analysis's findings are displayed in Table 4.3. Kodo millet, finger millet and BPF powder all have significant amounts of macronutrients, according to nutrient analysis. Out of the three basic materials, the analysis revealed that BPF powder had the highest energy density (398.72 kcal/100 gm), nearly twice as much protein (20.5%) and a greater fat content (7.8% in total). Compared to Finger and Kodo millets, BPF powder has a higher ash percentage (6.07%) and a lower carbohydrate content (61.5%). Out of all the ingredients, finger millet has the highest amount of carbohydrates (74.78%), crude fiber (about 2.68%) and moisture (12.78%). Overall, these findings confirm the nutritional complementarity of the three ingredients. While finger millet offers high carbohydrates and fiber, BPF contributes superior protein, fat, and mineral content. Their combined use in product development supports both nutritional adequacy and functional diversity, aligning with the formulation objectives of the extruded product *Smurfies*.

Table 4.3 Nutrition Analysis of Raw Ingredients

Nutrients	Finger millet (g/%) (*Eleusine coracana*)	Kodo millet (*Paspalum scrobiculatum*) (g/%)	BPF powder (g/%) (*Clitoria ternatea*)	Whey Protein Concentrates-80 (WPC-80) (g/%)
Energy (kcal)	344	357	398	371
Protein (g)	9.08	10.91	20.52	79.04
Carbohydrates (g)	74.78	74.21	61.52	28.59
Crude fiber (g)	2.68	0.92	0.1	-
Fat (g)	1.02	1.94	7.84	1.70
Moisture (g)	12.78	12.69	4.05	4.72
Total Ash (g)	2.34	0.25	6.07	5.15

4.1.2.4 Standardization and Extrusion Technique for *Smurfies* with Variable Blue Pea Flower Content

Smurfies enriched with blue pea flower powder were developed using a twin-screw extruder and a blend of whey protein concentrate, ragi, and kodri flours. The choice of BPF incorporation levels and extrusion temperatures was informed by Singh et al. (2022), who reported enhanced expansion, texture, and colour at higher BPF levels (0%, 5%, 10%) and elevated die temperatures (130°C and 150°C) when extruding yellow pea blends. The nutritional values of BPF in this study, particularly its high protein (20.52%), fat (7.84%), and ash (6.07%) content, closely align with findings by Weerasinghe et al. (2022), confirming BPF's richness in bioactives, essential minerals, and functional lipids.

4.2 Product Evaluation Phase

4.2.1 Comprehensive Evaluation of *Smurfies:* Chemical, Physical, Antioxidant, Microbial, Cost and Shelf-Life Analysis

4.2.1.1 Proximate Principles analysis of the *Smurfies*

Table 4.4 provides specifics on the parameters with their results.

Table 4.4 Proximate Analysis of 0%, 5% and 10% BPF Incorporated *Smurfies*

Smurfies	Energy (kcal)	Protein (g%)	Carbohydrates (g%)	Fats (g%)	Moisture (g%)	Total Ash (g%)
0% BPF	**357**	**12.3**	**76.51**	**0.22**	**8.24**	**2.66**
5% BPF	**359**	**12.54**	**76.67**	**0.35**	**7.64**	**2.80**
10% BPF	**359**	**13.20**	**75.63**	**0.41**	**7.96**	**2.80**

The proximate composition of the developed *Smurfies* with varying levels of Blue Pea Flower (BPF) powder (0%, 5% and 10%) was *analysed* to assess the nutritional impact of BPF incorporation. The results are summarized in Table 4.4. The energy content of all three formulations ranged from 357.5 to 359.99 kcal per 100 grams, indicating a marginal variation in caloric value with higher BPF levels. The highest energy value was observed in the 5% BPF incorporated *Smurfies* (359.99 kcal), followed closely by 10% BPF (359.01 kcal), and then the 0% BPF with 357.5 kcal per 100g. The slight increase in energy may be attributed to the higher fat and protein content of BPF compared to the base millets.

A progressive increase in protein content was noted with increasing levels of BPF, from 12.3% in the control to 13.20% in the 10% BPF sample. This aligns with the protein-rich profile of BPF powder (20.52% as per Table 4.3), suggesting its effectiveness in enhancing the protein density of the extruded product. On average, the protein content across all *Smurfies* variants was 12.68%, classifying it as a moderate protein food. Carbohydrate content remained relatively stable across all variants, ranging from 75.63% to 76.67%. The highest carbohydrate content was observed in the 5% BPF sample (76.67%), while the lowest was in the 10% BPF sample (75.63%). This minor reduction could be due to the substitution of millets with BPF, which has a lower carbohydrate content. In terms of fat content, a gradual increase was recorded with rising BPF levels—from 0.22% (0% BPF) to 0.41% (10% BPF). This reflects the higher fat content of BPF (7.84%), contributing to improved energy density and possibly affecting the mouthfeel of the product.

The moisture content slightly decreased from 8.24% in the control to 7.64% in the 5% BPF sample and 7.96% in the 10% BPF sample. Lower moisture values are beneficial for extended shelf life. Lastly, total ash content, which indicates mineral presence, increased from 2.66% in the control to 2.80% in both 5% and 10% BPF samples. This is consistent with BPF's higher Ash value (6.07%), suggesting better mineral fortification. Overall, the incorporation of BPF at 5% and 10% levels significantly improved the protein, fat, and ash content of *Smurfies* without compromising carbohydrate concentration or energy value. These findings support the potential of BPF as a valuable functional ingredient for enhancing the nutritional profile of extruded breakfast cereals. The proximate values of *Smurfies* are consistent with similar extruded protein-rich products. The protein content (12.3–13.2%) aligns with corn-soy (13.2%) and lupin-wheat (12.4–14%) extrudates. Carbohydrate levels in *Smurfies* (75.63–76.67%) are similar to corn-based extrudates (72–76%) (Singh et al., 2022). Fat content (0.22–0.41%) is lower than soy-based extrudates (1.5–2.8%) (Osman et al., 2024), reflecting the lean formulation. Moisture content (7.64–8.24%) falls within typical extruded product ranges (6–9%), ensuring shelf stability (Hussain et al., 2024). Ash content (2.66–2.80%) is also in alignment with lupin or chickpea-based extrudates (2.5–3.1%), indicating comparable mineral profiles and validating the use of BPF in enhancing nutritional quality.

4.2.1.2 Antioxidant Profiling of *Smurfies*

DPPH (2,2-diphenyl-1-picrylhydrazyl) Assay:

The antioxidant potential of the developed *Smurfies* was evaluated using the DPPH radical scavenging assay, initially standardized with ascorbic acid as the reference antioxidant. Due to the high starch content in millets, which impedes solubility in methanol, an acid hydrolysis step was performed using hydrochloric acid (HCl) in a methanol solution (mg/mL) to facilitate effective sample dissolution. A 0.5% aliquot of the hydrolysed mixture was added to each *Smurfies* variant and incubated in a water bath for 30 minutes, followed by vertexing for 10 minutes to ensure complete dissolution before initiating the DPPH assay.

Each sample was *analysed* in duplicate and the entire experiment was repeated three times (N=3). The antioxidant activity results were expressed as mean ± standard deviation (SD), ensuring statistical reliability. As presented in Table 4.5, the 10% BPF-incorporated *Smurfies* exhibited the highest DPPH radical scavenging activity at a concentration of 20 µg, indicating superior antioxidant capacity compared to the 0% and 5% BPF variants. This enhanced activity can be attributed to the increased incorporation of blue pea flower powder, a rich source of anthocyanins and other bioactive phytochemicals known for their free radical-neutralizing properties. The findings suggest a positive correlation between BPF concentration and antioxidant potential, supporting the functional role of BPF as a natural source of antioxidants in extruded cereal products. These results align with previous literature highlighting the antioxidant efficacy of *Clitoria ternatea* in functional food applications.

Table 4.5 Antioxidant Activity by DPPH

% RADICAL SCAVENGING ACTIVITY (% RSA)			
Concentration	**10 µg**	**15 µg**	**20 µg**
Standard (Ascorbic acid)	**49.53**	**49.53**	**97.82**
0% *Smurfies**	**46.78± 2.10**	**59.69± 1.95**	**69.28± 5.13**
5% *Smurfies**	**47.05± 4.04**	**60.88± 2.48**	**70.23± 3.04**
10% *Smurfies**	**48.38± 2.96**	**61.67± 3.90**	**71.58± 6.05**
****Values are expressed as mean ± standard deviation (n = 3).***			

The antioxidant activity of *Smurfies* samples was evaluated using the DPPH radical scavenging assay at concentrations of 10 µg, 15 µg, and 20 µg, and compared with ascorbic acid as a standard antioxidant. As shown in Table 4.5, all *Smurfies* samples demonstrated measurable radical scavenging activity (% RSA), with increasing trends across concentrations. At 10 µg, the 10% BPF-incorporated *Smurfies* showed the highest RSA % (48.38 ± 2.96), slightly below that of ascorbic acid (49.53%). The 0% and 5% BPF variants showed similar RSA values of 46.78 ± 2.10% and 47.05 ± 4.04%, respectively, indicating that even at low concentrations, BPF contributes positively to antioxidant activity. At 15 µg, the RSA improved across all samples, with 10% *Smurfies* again exhibiting the highest activity (61.67 ± 3.90%), followed by 5% *Smurfies* (60.88 ± 2.48%) and 0% *Smurfies* (59.69 ± 1.95%). Though the difference between 5% and 10% BPF samples was modest, a consistent pattern of enhanced antioxidant potential with higher BPF incorporation was evident.

At 20 µg, a more pronounced difference was observed. The 10% BPF *Smurfies* achieved the highest RSA value of 71.58 ± 6.05%, followed by 5% BPF (70.23 ± 3.04%) and 0% BPF (69.28 ± 5.13%). In comparison, the standard ascorbic acid exhibited a significantly higher RSA of 97.82%, as expected. Overall, these results demonstrate a dose-dependent increase in antioxidant activity across all formulations, with 10% BPF-incorporated *Smurfies* consistently showing superior performance at each concentration. The enhanced RSA values can be attributed to the presence of polyphenols and anthocyanins in the blue pea flower, which are known for their radical scavenging properties. These findings validate the use of BPF as a functional ingredient to improve the antioxidant profile of extruded breakfast cereals.

4.2.1.3 Textural characterization of *Smurfies*

4.6 Textural Characterization of *Smurfies*

Smurfies	Hardness (gf)	Crispiness
0% BPF	6523.10	292.512
5% BPF	4708.64	253.676

The textural characteristics of *Smurfies* were evaluated in terms of hardness and crispness, two key sensory attributes influencing consumer acceptance. Hardness, defined as the peak force required to fracture the snack, was found to decrease with the incorporation of Blue Pea Flower (BPF). Specifically, 0% BPF *Smurfies* exhibited a hardness of 6,523.10 gf, while the 5% BPF variant showed a reduced hardness of

4,708.64 gf, indicating a 27.8% decline. This reduction suggests a softer product matrix due to the inclusion of BPF. Similarly, crispness, assessed by the number of major positive peaks during compression, also declined with BPF incorporation. The crispness of 0% BPF *Smurfies* was 292.512 peaks, which decreased to 253.676 peaks in the 5% BPF formulation—a 13.3% reduction—implying a less brittle and potentially more melt-in-mouth texture.

4.2.1.4 Microbial Quality and Water Activity and its Influence on Storage of *Smurfies*

The microbial quality assessment of *Smurfies* (5% BPF) was conducted to ensure the product's safety and shelf stability. As shown in the table 4.7, the total bacterial count was found to be less than 10 $\log_{10}$ CFU/g, indicating an extremely low microbial load. This suggests that the processing and packaging methods employed were effective in minimizing bacterial contamination.

Moreover, total coliforms were nil, confirming the absence of any environmental contamination, which is a key indicator of hygienic handling and water quality during production. Similarly, yeast and mould were reported as absent, indicating no fungal growth, which is crucial for preventing spoilage and extending product shelf life.

4.7 Microbial Count of *Smurfies (5% BPF)*

Total Bacterial Count ($\log_{10}$ Cfu/g)	Total Coliform ($\log_{10}$ Cfu/g)	Yeast and Mould ($\log_{10}$ Cfu/g)
<10	Nil	Absent

The microbial quality of 5% BPF-incorporated *Smurfies* was monitored over a 7-week storage period under the accelerated storage conditions to assess the product's shelf stability. The Water Activity measures the amount of available water for microbial growth, with higher values indicating a higher risk of spoilage.

4.8 Influence of Storage Period on the Microbial quality and Water Activity *Smurfies (5% BPF)*

Parameter Analysed	Storage Period (weeks)							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Total Bacterial Count (TBC) (log10 CFU/g) (MEAN ± SD)	<10	<10	<10	<10	0.8	1.1	1.5	1.6
Yeast and Mould (log_{10} Cfu/g)	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent
Total Coliform (log_{10} Cfu/g)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Water Activity (A_w)	0.447	0.527	0.561	0.582	0.592	0.612	0.227	0.641

Total Bacterial Count (TBC) remained below detectable limits (<10 log□□ CFU/g) up to the third week of storage, indicating excellent microbial stability in the initial phase. A slight increase in bacterial load was observed from week 4 (0.8 log□□ CFU/g) onwards, rising gradually to 1.6 log□□ CFU/g by week 7. However, these values are still within acceptable safety limits for ready-to-eat extruded snack products and suggest no immediate risk of spoilage. Yeast and Mould were consistently absent throughout the 7-week period, highlighting the product's resistance to fungal growth, likely due to its low moisture content and proper packaging. This absence is crucial for preventing off-flavours, spoilage, and textural deterioration. Similarly, Total Coliforms remained nil across all weeks, indicating the maintenance of hygienic standards during preparation and handling. The absence of coliforms confirms that there was no post-processing contamination from water or environmental sources. It was anticipated since microorganisms, such as bacteria, moulds and yeasts, cannot thrive in water with an activity level below 0.70. The water activity the sample remained below 0.7 during storage as can be seen from table 4.9.

4.2.1.5 Cost Estimation of *Smurfies*

A thorough breakdown of the expenses associated with creating the *Smurfies* variations was part of the cost analysis method used in this study. Initially, the rates and quantities of each item used in *Smurfies* were taken into account while calculating the expenses of raw materials. The cost of *Smurfies* was then determined using the entire yield that was produced. And the cost was estimated for 100 grams of *Smurfies*.

Table 4.9 Ingredient Cost Analysis of *Smurfies (100g)*

Ingredients	*Smurfies* per 100 g		
	0% BPF (Rs.)	5% BPF (Rs.)	10% BPF (Rs.)
Ragi	**14**	**14**	**14**
Kodri	**6.75**	**6.75**	**6.75**
WPC- 80	**15.99**	**15.99**	**15.99**
BPF	**0**	**14.9**	**29.8**
Salt	**3**	**3**	**3**
Vanilla Essence	**60.6**	**60.6**	**60.6**
Total Cost	**100.34**	**115.24**	**130.14**

Table 4.10 Ingredient Cost Analysis of *Smurfies per 100g and 30g (serving size)*

Smurfies	COST (Rs.)		
Weight	0% BPF	5% BPF	10% BPF
100 g	100.34	115.24	130.14
30 g (Serving Size)	30.10	34.57	39.04

The ingredient cost analysis of *Smurfies* with 0%, 5%, and 10% Blue Pea Flower (BPF) incorporation is presented in Tables 4.10 and 4.11. For 100 g of product, the base ingredients—ragi (Rs. 14), kodri (Rs. 6.75), WPC-80 (Rs. 15.99), salt (Rs. 3), and vanilla essence (Rs. 60.6) remained constant across all formulations. The variation in total cost was attributed to the addition of BPF, priced at Rs. 14.90 and Rs. 29.80 for 5% and 10% incorporation levels respectively. Consequently, the total cost for 100 g increased from Rs. 100.34 in the 0% BPF variant to Rs. 115.24 and Rs. 130.14 for 5% and 10% BPF *Smurfies*, respectively. This represents a cost escalation of approximately 14.9% and 29.7% with increasing BPF content.

Table 4.11 further breaks down the cost per 30 g serving size, which is particularly relevant from a consumer affordability perspective. The cost per serving was calculated as Rs. 30.10 for 0% BPF, Rs. 34.57 for 5% BPF, and Rs. 39.04 for 10% BPF formulations. While the addition of BPF increases the production cost, it also enhances the nutritional value of the product through the inclusion of natural antioxidants and bioactive compounds. These results suggest that although BPF incorporation slightly raises the cost, the final product remains within a reasonable price range for premium or health-focused cereal products. The cost increments are justifiable considering the functional advantages offered by blue pea flower, especially in terms of antioxidant activity and visual appeal.

4.2.2 Evaluation of Glycaemic index of the Blue Pea flower incorporated *Smurfies*

The glycaemic response (GR) is a normal physiological phenomenon that happens after eating and is influenced by the rate of glucose entry into the circulation, the amount absorbed, the rate at which glucose disappears from the circulation due to tissue uptake and the hepatic control of glucose release. The effect of food on blood sugar levels after eating is measured by the Glycaemic Index (GI). The GI gives information about the potentially expected GR when an individual consumes a specific quantity of a food that has a predetermined amount of carbs. (Typically, 50 g). The incremental area-under-the-blood-glucose-curve (iAUC) over a two-hour period is used to assess GR, which is the increase in blood glucose levels that happens after eating.

Background information

Based on the inclusion and exclusion criteria, the subjects for the study were enrolled from the Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda. The study included 16 participants who provided their consent. There were 6 drop-outs therefore the sample size for this phase was 10. Using a pre-tested questionnaire, general information, socioeconomic level, health and family history was gathered. Using the standard methods, anthropometric measures of height, weight, waist circumference and hip circumference were obtained. During the study, fasting blood glucose levels were examined as biochemical parameter.

Socio- economic status

- Majority of the subjects (90%) followed Hindu religion whereas, 10% of the subjects followed Islam.
- The educational status shows that 40% of the subjects were post-graduates, 30% of the subjects were Undergraduates, 20% of the subjects were Graduates and 10% of the subjects were Ph. D scholars.
- All the subjects in the study were students.
- 60% of the subjects had a nuclear family and 40% of the subjects lived with joint family.
- 30% of the subjects had 5 family members and 30% had more than 5 members in the family.
- The Average Total Family Income (Monthly) is Rs. 1,53,500.

Anthropometric Measurements

The average height of the enrolled participants was 163.93 cm and their average weight was 60.2 kg. The individuals' normal weight range was indicated by the mean Body Mass Index (BMI), which was determined to be 21.84 kg/m² based on these data. The mean Waist-Hip Ratio (WHR) was 0.79 based on the average waist and hip circumferences, which were measured at 71.98 cm and 89.33 cm, respectively. Table 4 provides a summary of these anthropometric metrics.

Table 4.11 Socio-Economic Status of the Subjects (N, %)

Particulars	Subjects
Age (Mean± SD)	23.3± 2.35
Gender	
Females	7 (70)
Males	3 (30)
Religion	
Hindu	9 (90)
Muslim	1 (10)
Marital status	
Unmarried	10 (100)
Educational level	
Under- graduate	3 (30)
Graduate	2 (20)
Post- graduate	4 (40)
Ph. D	1 (10)
Type of Family	
Nuclear	6 (60)
Joint	4 (40)
Number of Family members	
3	2 (20)
4	2 (20)
5	3 (30)
More than 5	3 (30)
Total Family Income	
<50,000	3 (30)
50,000	1 (10)
>50,000	6 (60)

Table 4.12 Anthropometric Measurements of The Subjects (MEAN±SD)

Anthropometric measurement	Subjects
Weight (kg)	54.7± 5.37
Height (cm)	159.08± 7.01
BMI (kg/m^2)	21.81± 1.24
Waist circumference	71.98± 7.60
Hip circumference	89.33± 6.49
WHR	0.79± 0.05

Table 4.13 Family History of the Subjects (N, %)

Medical conditions	Mother	Father	Grandparents
Obesity	1 (10)	1 (10)	3 (30)
Diabetes Mellitus	2 (20)	1 (10)	2 (20)
Hypertension	0	2 (20)	4 (40)
Dyslipidemia	0	2 (20)	1 (10)
Stroke	0	0	2 (20)
Cancer	0	0	1 (10)
Cardiovascular Diseases	0	1 (10)	1 (10)
Thyroid	0	0	3 (30)
Asthma	0	0	0

Table 4.13 shows that hypertension (40%) and obesity (30%) were the most reported conditions among grandparents. Diabetes mellitus was prevalent in both mothers (20%) and grandparents (20%). Cardiovascular diseases and thyroid issues were observed in 10% of subjects' families, indicating hereditary risk for chronic non-communicable diseases.

Glycaemic index of BPF incorporated *Smurfies* was calculated by plotting an incremental area under curve of test *Smurfies* and standard *Smurfies*. Blood glucose responses were plotted and the incremental area under the curve (iAUC) was calculated using the trapezoidal method, following WHO/FAO guidelines (1998). Both the standard *Smurfies* (0% BPF incorporated) and test *Smurfies* (5% BPF incorporated) exhibits low Glycaemic index i.e., 53 and 51

TABLE 4.14 Glycaemic Index of *Smurfies*

Smurfies	Glycaemic index
0% BPF incorporated *Smurfies*	53
5% BPF incorporated *Smurfies*	51

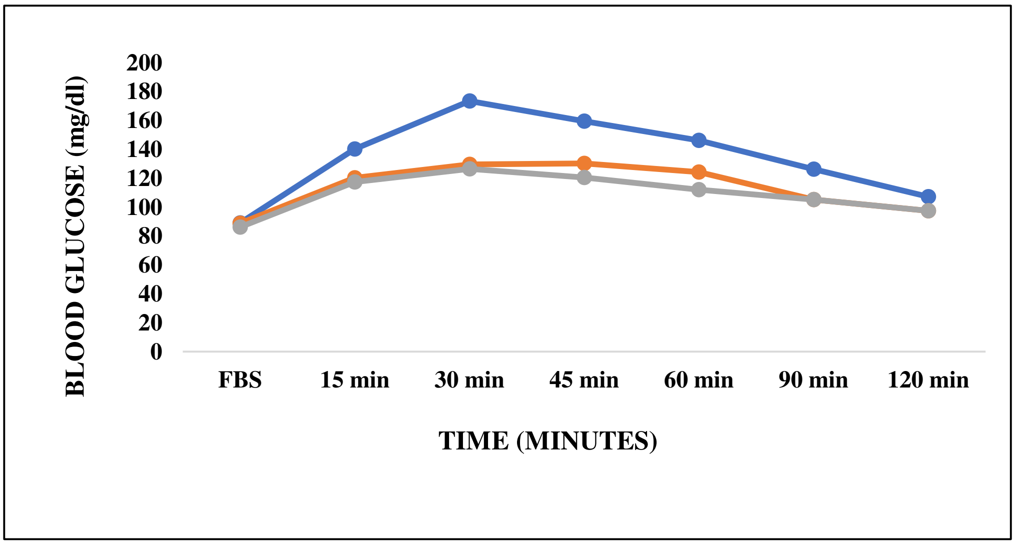

Figure 4.12 Blood Glucose Response of Both *Smurfies* Compared with Glucose

4.3 Product Application Phase

4.3.1 Development of Breakfast recipes featuring *Smurfies* as a key ingredient

Sensory evaluation was initiated of six *Smurfies* incorporated recipes specifically Parfait, Smoothie, Muffins, Bread, Granolas and Bars using a composite rating measure and a 9-point hedonic rating scale. For every recipe, three samples were developed. The control sample, or sample A, was devoid of BPF (0% *Smurfies*). There were 5% and 10% BPF-incorporated *Smurfies* in samples B and C, respectively. Using a composite rating scale and a 9-point hedonic rating scale, 30 to 35 semi-trained panellists were asked to score different aspects of each recipe. Following the sensory evaluation, the semi-trained panelists were asked to fill a pre-tested questionnaire about their demographics, perceptions of sustainability and local sourcing and their perceptions of nutrition and health. Table 4. 15 to table 4.20 shows the Composite score results of all *Smurfies* incorporated recipes with Mean± SD.

PARFAIT- A parfait is a layered dessert made out of yogurt or cream, fruits, and granola or other crunchy toppings, usually served in glass.

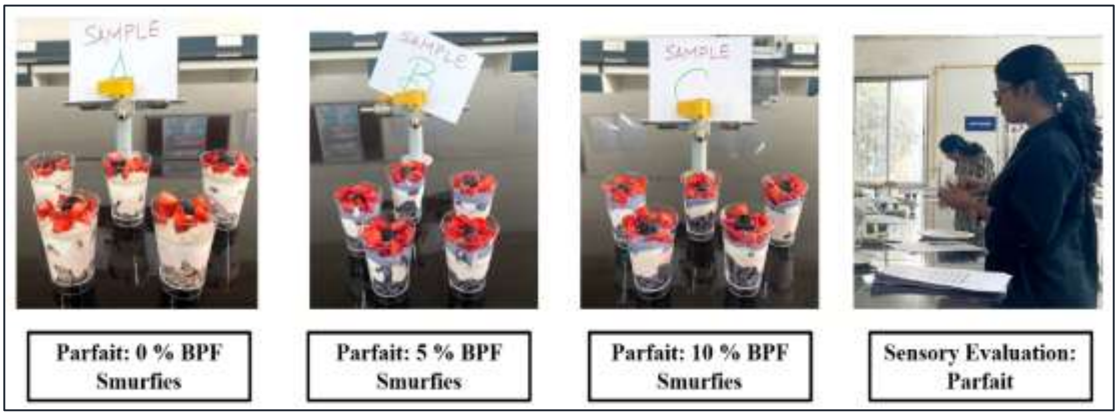

Figure 4.13 Parfait with varying levels of BPF *Smurfies* and Sensory Evaluation

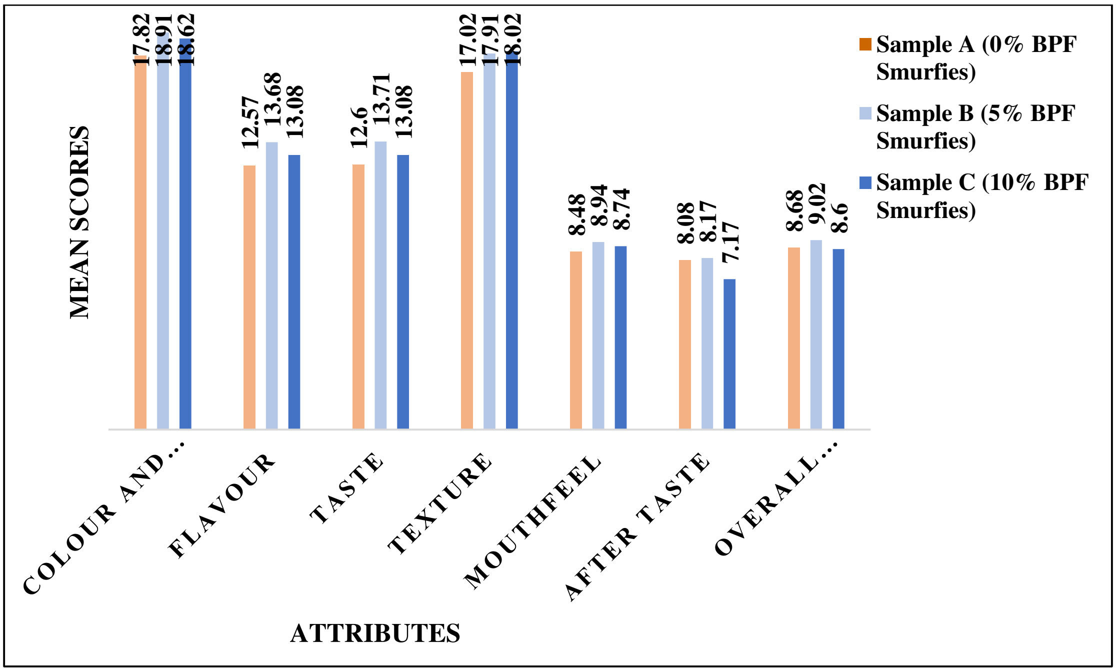

Figure 4. 14 Visual Representation of Mean Scores of Parfaits

Table 4. 15 Composite Scores for Parfait (MEAN±SD)

Attributes	*Max. Score*	*Sample A (0% BPF Smurfies)*	*Sample B (5% BPF Smurfies)*	*Sample C (10% BPF Smurfies)*
Colour and Appearance	20	17.82± 2.44	18.91± 1.40	18.62± 1.59
Flavour	15	12.57± 2.21	13.68± 1.32	13.08± 1.90
Taste	15	12.6± 2.06	13.71± 1.29	13.08± 1.75
Texture	20	17.02± 3.51	17.91± 2.36	18.02± 2.28
Mouthfeel	10	8.48± 1.17	8.94± 1.10	8.74± 2.04

After taste	10	8.08± 0.78	8.17± 0.85	7.17± 0.95
Overall acceptability	10	8.68± 1.27	9.02± 1.15	8.6± 1.64
Total score	100	85.28± 11.07	90.37± 8.26	87.34± 9.29

Sample B consistently scored higher than the other two samples in the majority of sensory attributes, such as colour and appearance (18.91), flavour (13.68), taste (13.71), texture (8.94), mouthfeel (9.02), and overall acceptability (9.02). This suggests that a moderate amount of blue pea flower improves the *Smurfies*' visual appeal and palatability. While Sample C did not do as well as Sample B in terms of taste and flavour, it did well in terms of appearance (18.62) and acceptability (8.60), suggesting that larger concentrations might not immediately improve sensory attributes. The fact that Sample A being the control sample received the moderate scores for the majority of attributes—especially aftertaste (8.08), demonstrated the beneficial effects of BPF addition.

SMOOTHIE

A smoothie is a thick, blended drink made from fruits or vegetables, often combined with yogurt, milk, or juice. It is commonly consumed as a nutritious breakfast or refreshing drink

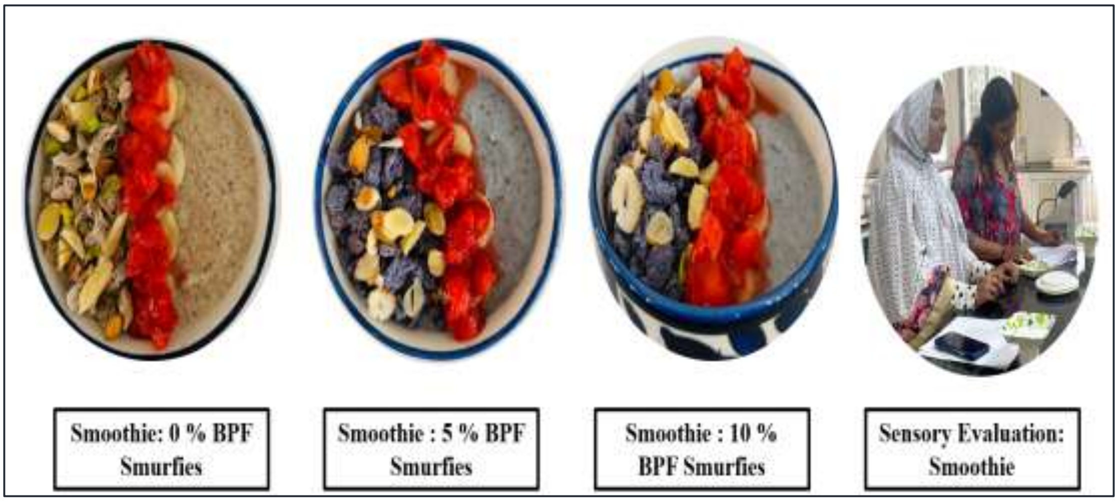

Figure 4.15 Smoothies with varying levels of BPF *Smurfies* and Sensory Evaluation

Table 4. 16 Composite Scores for Smoothie (MEAN±SD)

Attributes	*Max. Score*	*Sample A (0% BPF Smurfies)*	*Sample B (5% BPF Smurfies)*	*Sample C (10% BPF Smurfies)*
Colour and Appearance	20	17.71± 2.52	17.94± 2.27	18.57± 1.98
Flavour	15	12.54± 2.16	11.97± 2.22	11.85± 2.37
Taste	15	12.54± 2.22	12.54± 1.82	12.11± 2.33
Texture	20	16.28± 3.04	16.94± 2.97	16.34± 2.90
Mouthfeel	10	7.77± 1.73	7.91± 1.83	7.48± 1.94
After taste	10	7.77± 0.91	7.65± 0.90	7.74± 0.88
Overall acceptability	10	8.42± 1.65	8.42± 1.42	7.85± 1.70
Total score	100	83.05± 9.88	83.4± 13.46	81.97± 9.98

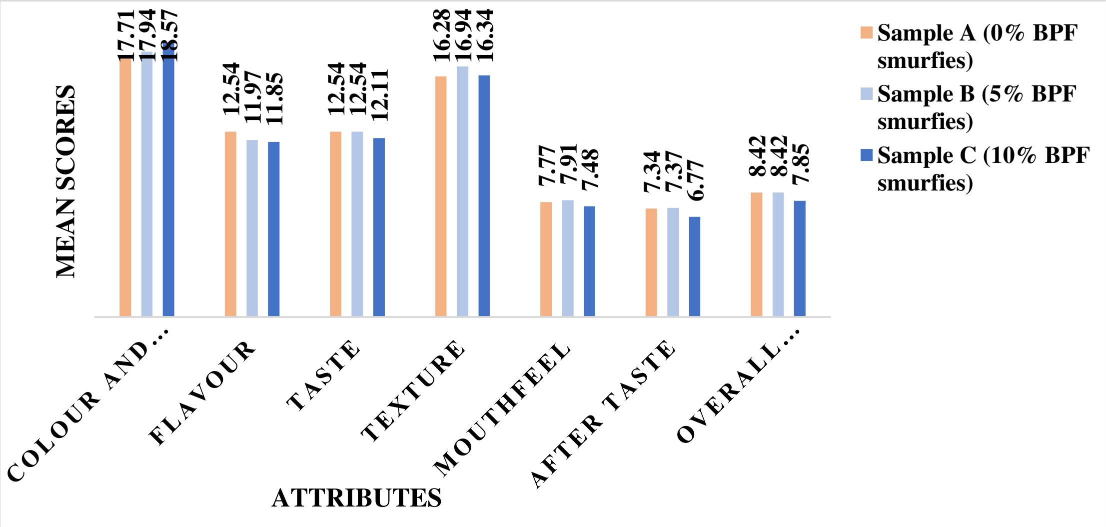

Figure 4. 16 Visual Representation of Mean Scores of Smoothies

The majority of the qualities in Sample B showed balanced and positive results, especially in flavour (12.54), texture (7.91), and overall acceptability (8.42). The greatest colour and appearance score (18.57) was obtained by Sample C, indicating that higher BPF concentration improves visual appeal but simultaneously higher BPF levels were giving more prominent aftertaste than other two samples. However, overall, 5% BPF was optimal for maintaining a balance between sensory quality and consumer acceptability.

MUFFINS

Breakfast muffins are single-serve, soft baked cakes that are frequently topped with nutritious grains, nuts, fruits, or vegetables. They are intended to be a quick, easy, and wholesome breakfast choice.

Figure 4.17 Muffins with varying levels of BPF *Smurfies* and Sensory Evaluation

Table 4.17 Composite Scores for Muffins (MEAN±SD)

Attributes	*Max. Score*	*Sample A (0% BPF Smurfies)*	*Sample B (5% BPF Smurfies)*	*Sample C (10% BPF Smurfies)*
Colour and Appearance	20	17.77± 2.50	18.37± 2.18	16.31± 3.26
Flavour	15	12.51± 1.97	12.45± 2.47	11.94± 2.02
Taste	15	13.11± 2.29	12.68± 1.93	12.28± 2.49
Texture	20	17.57± 3.37	17.48± 2.16	15.4± 4.62
Mouthfeel	10	8.05± 1.45	8.62± 1.66	7.88± 1.64
After taste	10	7.51± 0.95	7.91± 0.85	7.91± 0.91
Overall acceptability	10	8.77± 1.69	8.62± 1.39	8.08± 1.80
Total score	100	85.31± 9.91	86.17± 8.82	79.82± 12.53

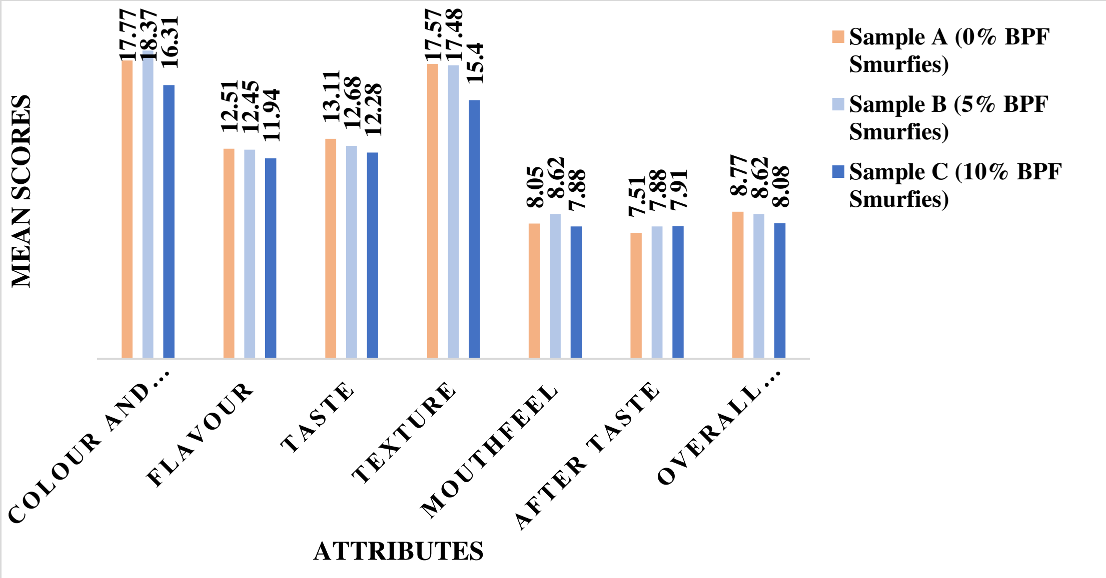

Figure 4.18 Visual Representation of Mean Scores of Muffins

The results showed that Sample B was the most favoured sample overall. It obtained the highest scores for colour and appearance (18.37), texture (8.62), and flavour (12.45), taste (12.68), and overall acceptability (8.62). Closely behind Sample C was Sample A, which scored somewhat lower on taste (13.11) and flavour (12.51), but better on mouthfeel (8.05) and acceptability (8.77). Higher BPF concentrations may marginally reduce overall sensory appeal, as Sample C received the lowest scores in all other important sensory parameters, including colour and appearance (16.31), flavour (11.94), and taste (12.28), despite having respectable ratings for texture (7.88) and overall acceptability (8.08).

BREAD

Bread is commonly used as a quick, versatile base for various dishes. It is frequently eaten as toast, sandwiches, or with other foods and can be buttered, toasted, or topped with spreads or eggs. It provides carbohydrates for energy to start the day.

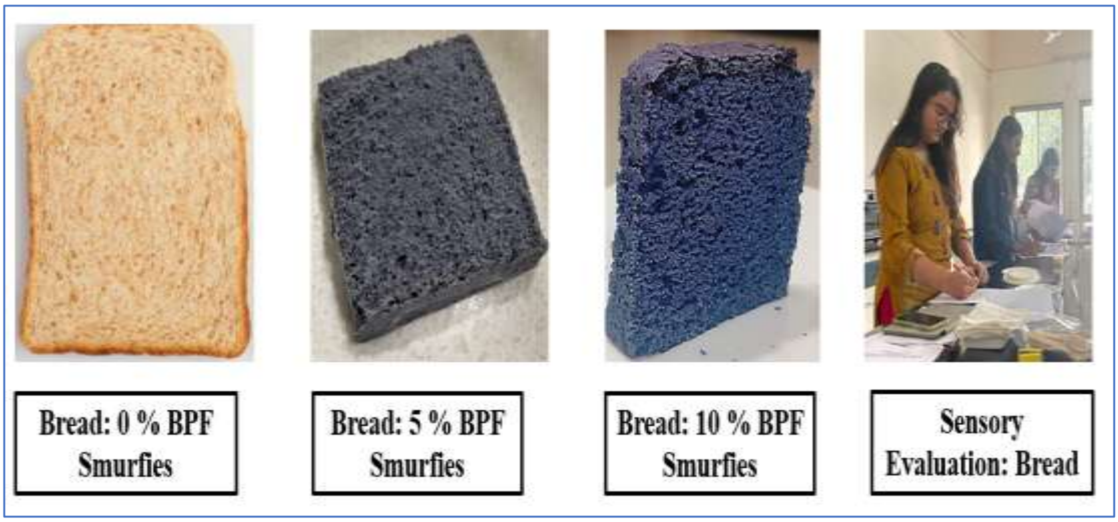

Figure 4.19 Breads with varying levels of BPF *Smurfies* and Sensory Evaluation

Table 4.18 Composite Scores for Bread (MEAN±SD)

Attributes	Max. Score	Sample A (0% BPF *Smurfies*)	Sample B (5% BPF *Smurfies*)	Sample C (10% BPF *Smurfies*)
Colour and Appearance	20	17.25± 1.55	17.88± 2.38	17.54± 2.82
Flavour	15	12.02± 1.04	10.42± 2.84	11.48± 3.00
Taste	15	11.08± 2.88	11± 2.73	10.17± 2.89
Texture	20	14.65± 3.78	16.25± 4.45	16.77± 3.85
Mouthfeel	10	7.48± 1.80	7.14± 2.11	7.51± 1.94
After taste	10	7.17± 1.59	6.85± 1.47	6.71± 1.44
Overall acceptability	10	7.74± 1.59	7.28± 1.91	7.77± 1.71
Total score	100	77.42± 7.84	76.85±12.34	77.97± 13.63

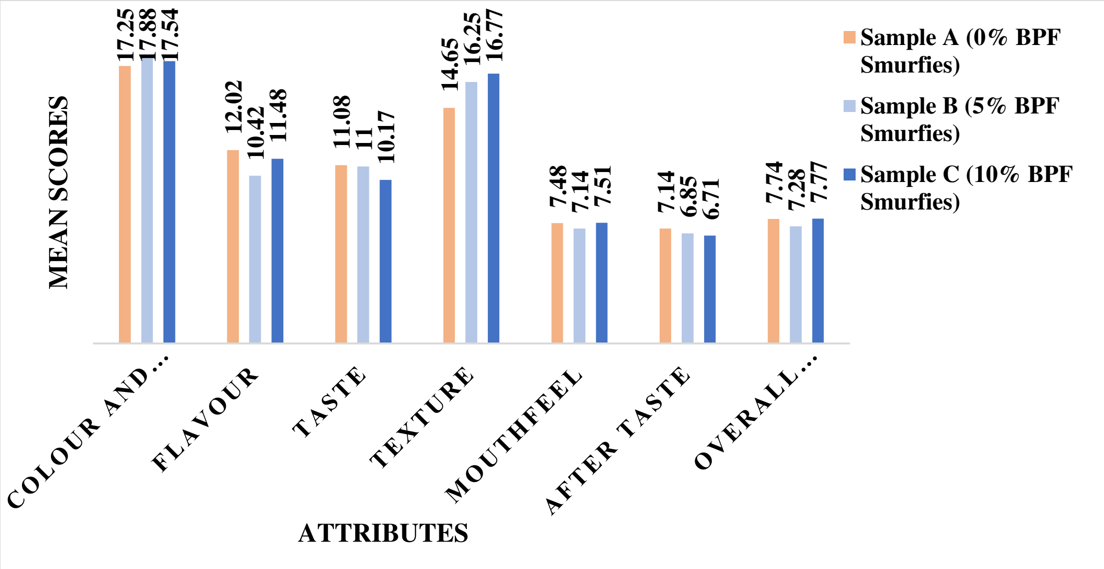

Figure 4.20 Visual Representation of Mean Scores of Breads

According to taste (10.17), colour and appearance (17.54), and overall acceptability (7.77), Sample C was the most favoured, indicating that a higher BPF concentration improved both visual and taste appeal. With the best scores for flavour (12.02) and mouthfeel (7.48) and the second-highest overall acceptability score (7.74), Sample A demonstrated a positive reaction to the conventional formulation. Sample B (5% BPF) received lower scores for taste (11), flavour (10.42), and overall acceptability (7.28), even though it had the greatest colour and appearance score (17.88). While texture and mouthfeel stayed largely consistent across all samples, 10% BPF seemed to provide the best overall mix of visual appeal, flavour, and acceptability.

GRANOLAS

Granolas are crunchy breakfast cereal or snack make from a blend of rolled oats, nuts, seeds, sweeteners (like honey or maple syrup), and sometimes dried fruits until golden and crisp. They are often eaten with milk, yogurt, or as a topping for smoothie bowls

Figure 4.21 Granolas with varying levels of BPF *Smurfies* and Sensory Evaluation

Table 4. 19 Composite Scores for Granolas (MEAN±SD)

Attributes	*Max. Score*	*Sample A (0% BPF Smurfies)*	*Sample B (5% BPF Smurfies)*	*Sample C (10% BPF Smurfies)*
Colour and Appearance	20	17.17± 1.74	18.65± 1.28	17.8± 2.13
Flavour	15	12.11± 1.25	13.34± 1.30	12.88± 1.36
Taste	15	12.08± 1.40	13.25± 1.48	13.14± 1.33
Texture	20	17.34± 2.66	18.71± 2.15	18.25± 1.42
Mouthfeel	10	8.02± 1.48	8.71± 1.10	8.62± 1.11
After taste	10	7.94± 0.99	8.28± 0.66	7.57± 1.00
Overall acceptability	10	7.88± 1.65	8.62± 1.21	8.37± 1.26
Total score	100	82.57± 7.75	89.22± 6.44	86.65± 5.93

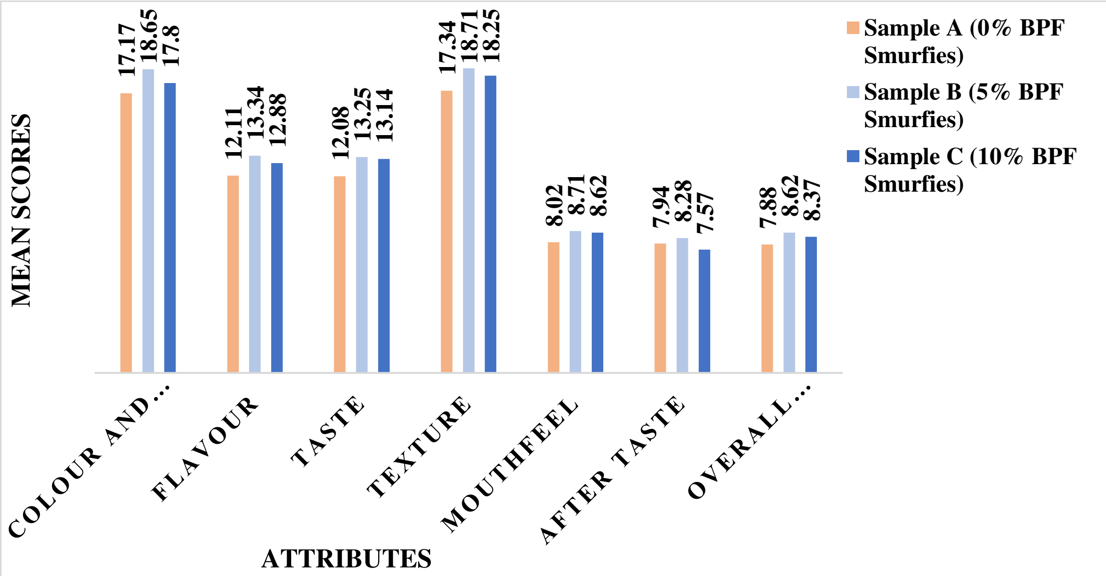

Figure 4. 22 Visual Representation of Mean Scores of Granolas

In terms of colour and appearance (18.65), texture (18.71), and flavour (13.34), Sample B was the most favoured, demonstrating the beneficial effects of moderate BPF integration on sensory appeal. With an overall acceptability of 8.37, Sample C had the moderate taste score (13.14), along with strong ratings for colour (17.80) and texture (18.25), suggesting acceptable sensory balance at a higher BPF level. Overall, Samples B and C were both well-accepted, with Sample B slightly outperforming in most sensory parameters, suggesting that 5% BPF is an optimal level for enhancing the sensory qualities of *Smurfies*.

BARS

Bars are small, ready-to-eat snacks that are usually created by compressing components into a rectangle form, such as oats, nuts, seeds, dried fruits, sweeteners (such honey or syrup), and occasionally protein or chocolate. They are frequently used as energy boosters, meal replacements, or breakfast substitutes.

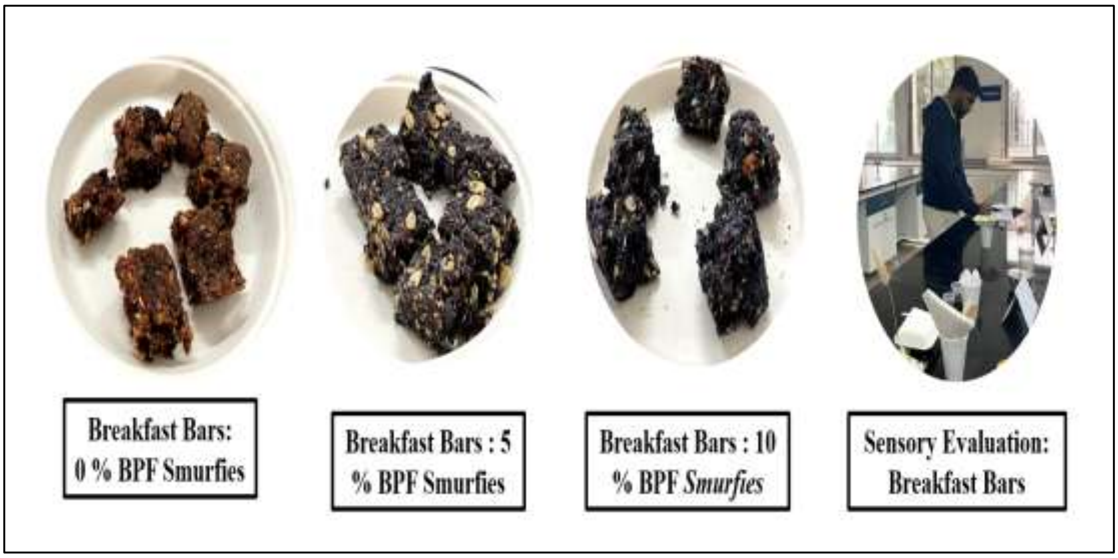

Figure 4.23 Breakfast Bar with varying levels of BPF *Smurfies* and Sensory Evaluation

Table 4. 20 Composite Scores for Bars (MEAN±SD)

Attributes	*Max. Score*	*Sample A (0% BPF Smurfies)*	*Sample B (5% BPF Smurfies)*	*Sample C (10% BPF Smurfies)*
Colour and Appearance	20	18.37± 1.78	18.02± 2.13	17.65± 2.68
Flavour	15	13.88± 1.52	13.31± 2.42	13.14± 1.75
Taste	15	13.54± 1.57	12.45± 1.59	12.51± 1.96
Texture	20	17.02± 2.74	16.88± 2.90	15.77± 4.03
Mouthfeel	10	9.14± 1.16	7.94± 1.67	8.22± 1.71
After taste	10	8.4± 0.97	8.17± 1.04	7.82± 1.27
Overall acceptability	10	8.88± 1.27	7.97± 1.33	8.17± 1.63
Total score	100	88.91± 7.85	85.11± 9.94	83.31± 12.21

Across the majority of qualities, Sample B (5% BPF *Smurfies*) obtained the most positive and balanced results. It received the moderate scores for Texture (16.88) and Colour and Appearance (18.02), suggesting that the addition of 5% blue pea blossom improved structural and visual attributes. Samples B and A received somewhat lower ratings for flavour and taste (13.31 and 12.45, respectively) than Sample B (13.88 and 13.54).

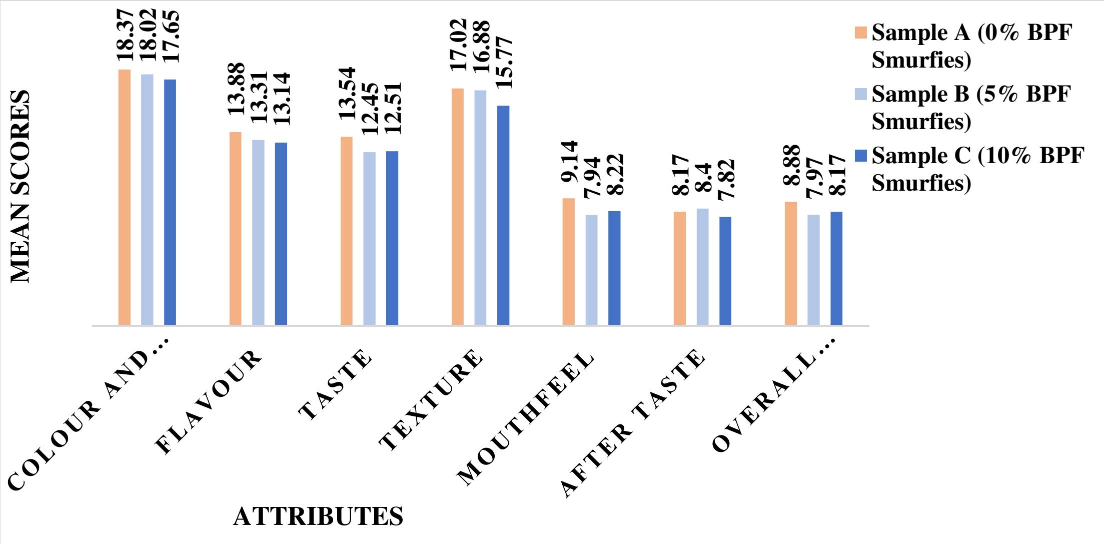

Figure 4.24 Visual Representation of Mean Scores of Bars

Despite having the highest Flavour and Taste scores, Sample A had the moderate Aftertaste (8.17) and Mouthfeel (9.14). In comparison to Sample B, Sample C had a modest decline in all parameters, indicating that the product's palatability may have suffered from a greater BPF concentration. Overall acceptability was highest in Sample A (8.88), followed closely by Sample C (8.17) and B (7.97), highlighting consumer preference for lower or moderate BPF inclusion.

Table 4.21 9- Point Hedonic Scores of BPF Incorporated Recipes (MEAN±SD)

Recipes	9- POINT HEDONIC RATING SCALE		
	Sample A (0% BPF *Smurfies*)	**Sample B (5% BPF *Smurfies*)**	**Sample C (10% BPF *Smurfies*)**
Parfait	7.88± 0.93	8.28± 0.78	8.22± 0.91
Smoothie	7.22± 1.05	7.42± 1.19	7.02± 1.42
Muffins	7.31± 1.13	7.54± 0.88	6.85± 1.41
Bread	6.34± 1.41	6.22± 1.84	6.71± 0.89
Granola	7.31± 1.02	7.85± 1.14	7.37± 0.91
Bars	7.54± 0.85	7.05± 1.43	7.28± 0.85

According to the 9-point hedonic rating scale, Sample B consistently scored top in a number of product categories, as shown by the data in Table 4 . In particular, the parfait's Sample B had the highest mean score, demonstrating a high level of customer preference. Likewise, Sample B was rated highest for smoothies, muffins, and granolas, indicating that it had positive sensory qualities in all of these products. But out of the three samples, Sample C received the greatest scores in the bread category, making it the most popular. Sample A, on the other hand, had the highest hedonic ratings for bars, suggesting a clear preference pattern in this product category. These results suggest that while Sample B generally performed best across most categories, consumer preferences varied depending on the specific product type.

Table 4.22 Comparative Ranking of BPF Powder Incorporated *Smurfies* Recipes as Per 9- Point Hedonic Scale

Ranking	Recipes
1	Parfait
2	Granola
3	Muffins
4	Smoothie
5	Bars
6	Bread

According to the table 4. 22 The following order was assigned to the recipes based on their overall sensory acceptability: The most popular item was parfait, which was followed by granola, muffins, and smoothie. Bread was ranked lowest, and bars were ranked fifth. This suggests that of the produced goods, parfait and granola were the most popular. The findings indicate that the panellists enjoyed all three *Smurfies* variations. This suggests that the participants liked the BPF-incorporated *Smurfies*

Table 4. 23 Nutritional Values of The Recipes with Cost (Per Serving)

Sr. No	Recipe	Energy (kcal)	Protein (g)	CHO (g)	Fats (g)	Cost (Rs.)
1	**Parfait**					
	(0% BPF)	217	8.42	32.32	6.08	**52.4**
	(5% BPF)	218	8.47	32.37	6.12	**56.87**
	(10% BPF)	219	8.67	32.05	6.14	**61.34**
2	**Smoothie**					
	(0% BPF)	308	10.67	38.58	12.71	**48.65**
	(5% BPF)	309	10.68	38.59	12.72	**49.32**
	(10% BPF)	311	10.71	38.54	12.72	**49.94**
3	**Bread**					
	(0% BPF)	49	1.69	9.97	0.22	**2.51**
	(5% BPF)	53	1.69	10.97	0.22	**2.71**
	(10% BPF)	54	1.70	10.98	0.22	**2.91**
4	**Bars**					
	(0% BPF)	150	3.01	29.78	2.07	**23.23**
	(5% BPF)	150	3.03	29.80	2.09	**23.68**
	(10% BPF)	150	3.05	29.82	2.11	**24.13**
5	**Muffins**					
	(0% BPF)	207	3.84	33.12	6.34	**21.12**
	(5% BPF)	206	0.20	1.22	0.005	**21.36**
	(10% BPF)	208	3.86	33.11	6.34	**21.6**
6	**Granola**					
	(0% BPF)	371	11.19	57.84	10.88	**91.07**
	(5% BPF)	372	11.24	57.89	10.92	**95.54**
	(10% BPF)	373	11.44	57.57	10.94	**156.33**

Table 4.23 presents the nutritional composition and cost analysis of six developed breakfast recipes—Parfait, Smoothie, Bread, Bars, Muffins, and Granola—incorporated with 0%, 5%, and 10% BPF. Overall, the incorporation of BPF showed a

minimal yet consistent increase in protein and fat content across most recipes. For instance, in parfaits, protein content increased from 8.42 g (0% BPF) to 8.67 g (10% BPF), and similar trends were observed in smoothies and bars. This rise could be attributed to the inherent nutritional quality of BPF, which enhances the protein profile of the recipes. Fat content also showed a slight increase, particularly in smoothies and muffins.

Energy values fluctuated marginally but remained relatively stable, indicating that BPF inclusion does not significantly alter the caloric density of the recipes. However, carbohydrate content showed slight reductions in some cases (e.g., muffins and bread with 5% BPF), suggesting BPF may slightly dilute the carbohydrate concentration.

Cost analysis revealed a gradual increase with higher BPF levels. For example, granola's cost rose from Rs. 91. 07 (0% BPF) to Rs. 156.33 (10% BPF), possibly due to the additional ingredient. Despite the increase, the nutritional enhancement supports BPF's potential as a value-adding functional ingredient in breakfast cereals.

4.3.2 Sensory assessment of *Smurfies*- based breakfast recipes

1. **Gender of panelist**

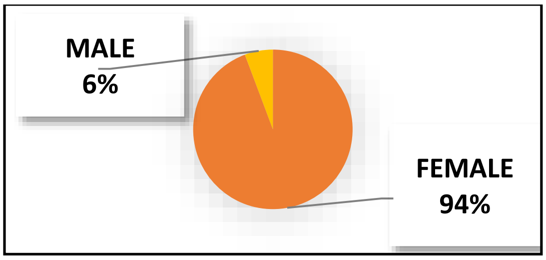

Figure 4.25 Gender of Panelists

According to the above figure 4.25, majority of the panelists were Females with 94% females and 6% males.

2. Occupation of panelists

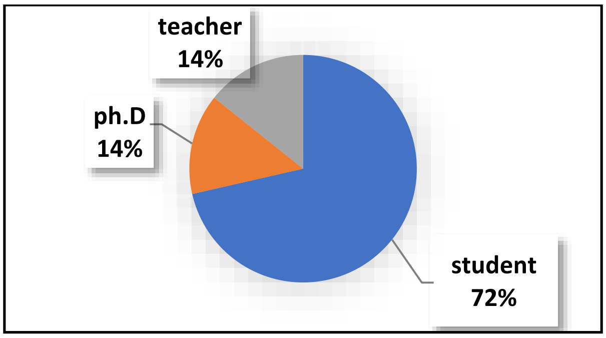

FIGURE 4.26 Occupations of the Panelists

From the above figure 4. 26 Maximum panelists were students i.e., 72%, followed by 14% panelists who are currently pursuing Ph.D. and 14% professors from the Department of Foods and Nutrition.

3. Do you regularly consume Breakfast cereals

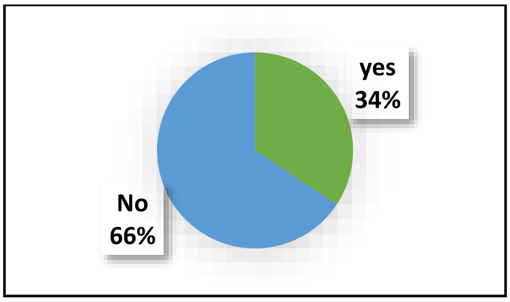

FIGURE 4.27 Consumption of Breakfast Cereals

According to the figure 4.27 Out of 35, only 34% panelists consume breakfast cereals regularly. Majority of the panelists do not consume breakfast cereals on regular basis.

4. How many times a week do you eat breakfast cereal?

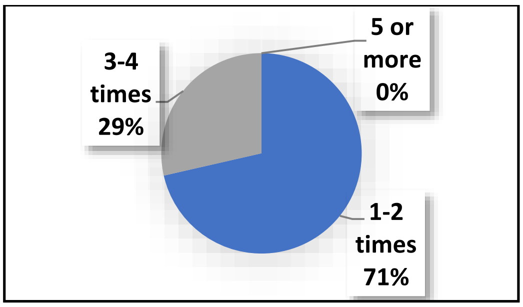

Figure 4.28 Frequencies of Having Breakfast Cereals

From the above Figure 4. 28 majority of the panelists (71%) consumes breakfast cereals only 1-2 times in a week. Only 29% panelists consume at least 3-4 times a week, but none of them consumes breakfast cereals regularly.

5. **How healthy do you think this breakfast cereal is compared to your regular breakfast cereal?**

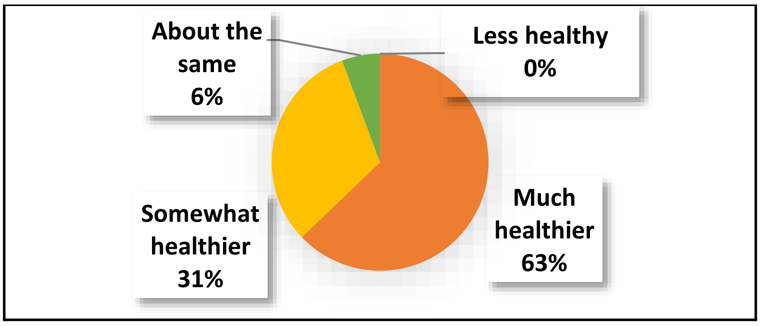

FIGURE 4.29 Breakfast Comparison

According to figure 4.29, 63% of panelists believe that *Smurfies* as breakfast cereal is much healthier than what they consume as breakfast cereals, followed by 31% panelists thinks that it is somewhat healthier.

6. **Do you think the inclusion of BPF and millets make this cereal more nutritious?**

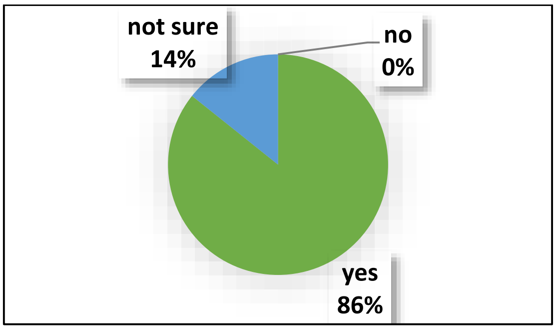

FIGURE 4.30 BPF Inclusion Acceptance

According to the graph above (Figure 4.30), 86% of panel members thinks that inclusion of BPF and millets makes *Smurfies* more nutritious. Out of total, 14% panelists were not sure about the inclusion.

7. Are you aware of the antioxidant benefits of BPF?

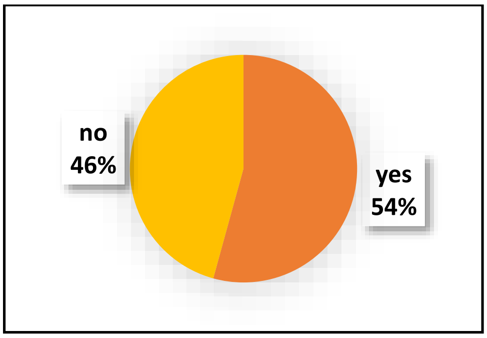

FIGURE 4.31 Awareness of BPF Antioxidants Benefits

According to the Figure 4.31, 54% panel members are aware of the fact that BPF contains antioxidants. While 46% panel members are not aware of the antioxidants present in BPF.

8. Would you consider switching to a cereal that contains millets and BPF for its nutritional benefits?

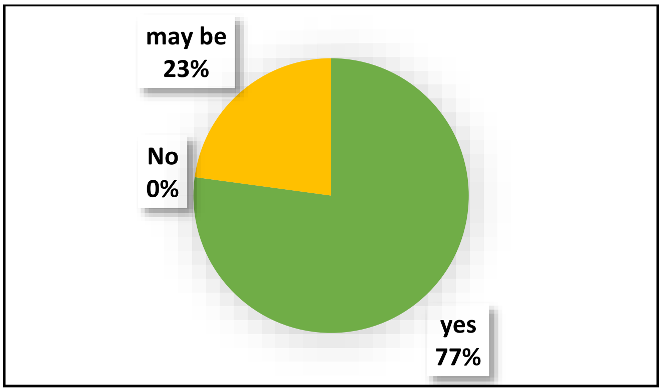

Figure 4.32 Willingness to Switch Over to Millets and BPF

According to the above Figure 4.32, 77% of panelists would consider switching to a cereal which contains millets and BPF for its nutritional benefits. While 23% were undecisive about the same.

9. How important is it to you that the cereal is high in Protein (from milk proteins like whey)?

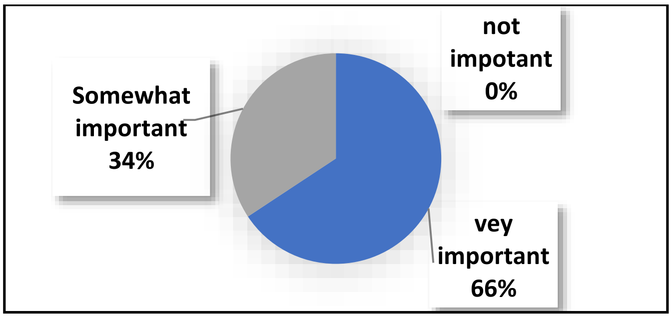

Figure 4.33 Importance of High Protein in Breakfast Cereal

From the Figure 4.33, 66% panelists find it as an important information that this cereal is high in protein content. While for 34% panelist it is somewhat important.

10. Does the fact that this cereal uses locally sourced ingredients (millets and BPF) influence your decision to buy it?

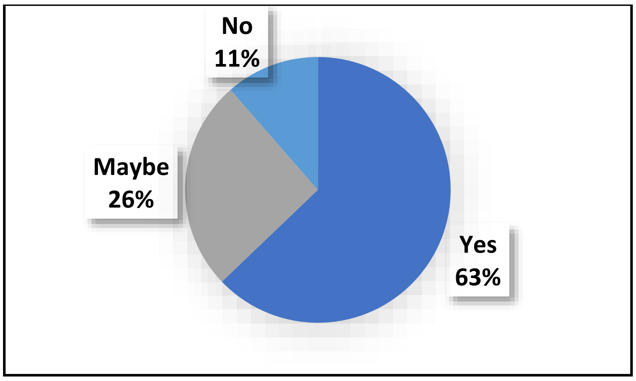

FIGURE 4.34 Awareness of Local Availability

From the above Figure 4.34, 63% of panelists would consider to buy this cereal if they know that this cereal uses locally sourced ingredients like millets and BPF. While 26% panelists may or may not consider this fact.

11. How important is it to you that the cereal is made using sustainable ingredients like drought- resistant millets?

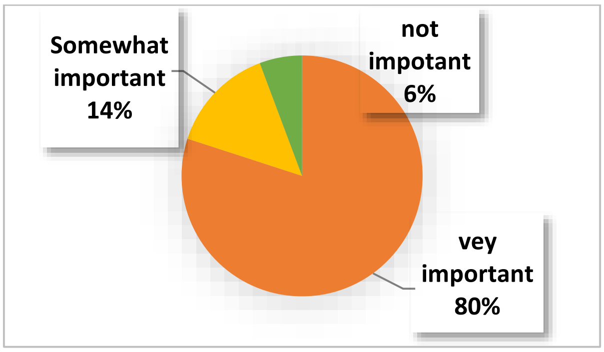

FIGURE 4.35 Importance of Use of Sustainable Ingredients

According to the graph (Figure 4.35) 80% of panelists find the information very important that this cereal is made using sustainable ingredients like drought-resistant millets while for 14% panelist it is somewhat important.

12. Would you pay more for a cereal that promotes sustainability and uses local ingredients?

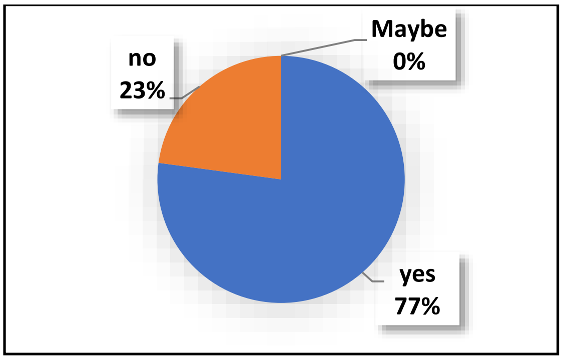

FIGURE 4.36 Purchase Decision Based on Price

According to the chart given (Figure 4. 36) 77% of panel members would pay more for the cereal that promotes sustainability and uses local ingredients. While 23% panel members neglected.

13. Would you consider incorporating this cereal into your regular breakfast routine?

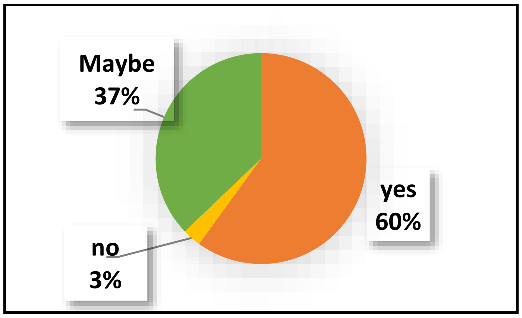

FIGURE 4.37 Willingness for Incorporation of Cereal

According to the Figure 4.37, 60% of panelists would consider incorporating *Smurfies* into their regular breakfast routine. While other 37% panelist may or may not incorporate.

14. What do you like most about this cereal?

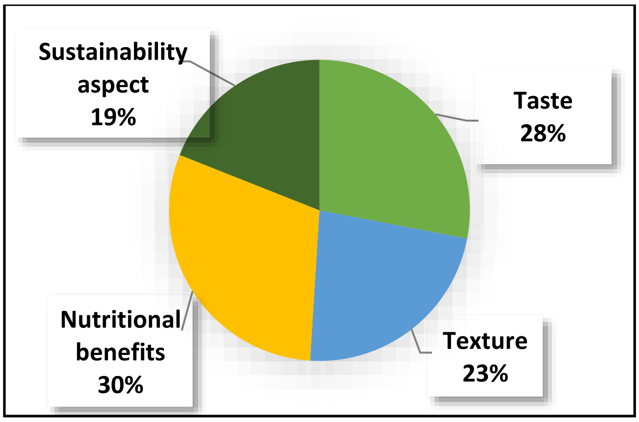

FIGURE 4.38 Attributes of the Cereal.

According to the Figure 4.38, Majority of the panelists i.e., 30% liked the nutritional benefits of the *Smurfies*, followed by its taste (28%) and texture and lastly its sustainability aspects with 19%

SUMMARY AND CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 Summary of the Study

In response to increasing consumer awareness about functional foods and the growing demand for nutritious, quick breakfast options, this research aimed to develop an innovative, health-oriented extruded breakfast cereal, coined as "Smurfies." The product was enriched with Blue Pea Flower (Clitoria ternatea)—a known source of natural antioxidants—combined with millets (ragi and kodri) and whey protein concentrate (WPC-80) to create a nutrient-dense, sustainable cereal suitable for the modern Indian lifestyle.

The study was carried out in three systematic phases:

Phase I: Market Survey and Product Development

A comprehensive market survey of 45 commercial breakfast cereal products across 12 brands provided critical insights into prevalent formulations, nutritional gaps, cost, ingredient trends, and consumer demand. It was observed that most products relied heavily on refined cereals, sweeteners, and additives, with limited incorporation of traditional grains like millets and functional components such as natural protein sources or antioxidant-rich ingredients. These findings helped identify the scope for innovation through indigenous grains and botanicals like Blue Pea Flower.

Following this, Smurfies were developed using extrusion technology, incorporating Blue Pea Flower at three levels (0%, 5%, and 10%). The selection of high-quality millets, milk protein (WPC-80), and lyophilized Blue Pea Flower powder was guided by nutritional profiling, availability, and functional compatibility. The standardization process focused on achieving optimal blend ratios and processing conditions for creating a shelf-stable, visually appealing, and palatable product.

Phase II: Product Evaluation

This phase involved chemical, antioxidant, physical, microbial, and economic evaluations, followed by a glycaemic index study.

5.2.1 Proximate and Antioxidant Analysis

The nutritional assessment showed a progressive increase in protein (12.3% to 13.2%), fat (0.22% to 0.41%), and ash content (2.66% to 2.80%) with increasing Blue Pea incorporation, while carbohydrate content remained relatively stable. Notably, the antioxidant potential measured using DPPH assay exhibited a significant rise in radical scavenging activity in 10% BPF Smurfies (up to 71.58%), confirming the functional advantage of Clitoria ternatea as a bioactive enhancer.

5.2.2 Texture, Microbial Quality, and Shelf Life

The texture analysis revealed a favorable reduction in hardness (from 6523.10 gf to 4708.64 gf) and crispness with BPF addition, offering a pleasant mouthfeel. Microbial evaluation confirmed excellent hygienic standards, with negligible bacterial count, no yeast or mould, and water activity consistently below 0.7 across 7 weeks—indicating shelf stability under ambient conditions.

5.2.3 Cost Analysis

While the ingredient cost per 100g increased from Rs. 100.34 (0% BPF) to Rs. 130.14 (10% BPF), this was deemed acceptable given the enhanced nutritional profile and sensory quality. The cost per serving (30g) ranged from Rs. 30.10 to Rs. 39.04, making it reasonably priced for a premium health-oriented product.

5.2.4 Glycaemic Index Study

A controlled GI study with human subjects demonstrated that both 0% and 5% BPF Smurfies had low glycaemic indices (53 and 51 respectively). These values make Smurfies suitable for individuals aiming to manage postprandial glucose levels, including diabetics and health-conscious consumers.

Phase III: Product Application and Sensory Evaluation

To explore real-world applications, six breakfast recipes—Parfait, Smoothie, Muffins, Bread, Granola, and Bars were developed using Smurfies with 0%, 5%, and 10% BPF. These were evaluated by semi-trained panelists using a composite scorecard and 9-point hedonic scale.

Across all recipes, the 5% BPF version (Sample B) emerged as the most favored in terms of colour, taste, texture, mouthfeel, and overall acceptability. In particular:

- Parfait and Granola ranked highest in overall preference.
- Bars and Breads, though nutritionally dense, received slightly lower scores for aftertaste at higher BPF levels.
- The nutritional composition of recipes showed improved protein and fat content without significant calorie increments.

A consumer perception survey further revealed that:

- 63% of panelists considered Smurfies healthier than their regular breakfast cereals.
- 86% believed BPF and millets made the product more nutritious.
- 77% were willing to switch to cereals with millets and BPF.
- 80% valued the use of sustainable, drought-resistant millets.
- 77% were open to paying more for products promoting local sourcing and sustainability.

These findings reinforced Smurfies' acceptability and market potential, especially among educated, health-aware urban populations.

5.2 Conclusion

The research successfully fulfilled its objective of developing a nutritionally enhanced, antioxidant-rich, low-GI breakfast cereal using Blue Pea Flower, millets, and whey protein, and evaluating its applications in everyday breakfast recipes.

Key conclusions include:

- Blue Pea Flower significantly improved protein, fat, ash content, and antioxidant activity of the extruded product without negatively affecting its energy value or sensory properties.
- A 5% BPF incorporation was optimal for maximizing nutritional enhancement and consumer acceptability.
- The final product is microbiologically safe, cost-effective, and shelf-stable, making it a viable commercial offering.
- Recipe-level application demonstrated that Smurfies can be successfully integrated into a variety of commonly consumed breakfast formats with high consumer appeal.
- The product aligns with current trends in functional foods, sustainability, and local sourcing, responding to health, environmental, and cultural needs.

Thus, Smurfies holds strong potential as a value-added, indigenous, health-oriented cereal product that bridges the gap between nutrition, convenience, and culinary innovation.

Recommendations for Future Research

- **Clinical validation** of long-term health effects (e.g., antioxidant capacity, metabolic parameters).
- **Scale-up trials** to optimize industrial extrusion conditions for large-scale manufacturing.
- **Packaging innovations** to enhance shelf-life and consumer appeal.
- Exploration of **alternate protein sources** (e.g., plant-based proteins) for vegan formulations.
- Further diversification of **recipe applications** (e.g., energy bites, savory snacks).

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APPENDICES

Institutional Ethics
Committee for Human
Research
(IECHR)

FACULTY OF FAMILY AND COMMUNITY SCIENCES
THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA

Ethical Compliance Certificate 2024-2025

This is to certify Ms. Hetvi Salunke study titled; "Development and Characterization of '*Smurfies*': A Blue Pea Flower (*Clitoria ternatea*) Powder - Enriched Extruded Millet and Milk Protein-Based Breakfast Cereal.." from Department of Foods and Nutrition has been approved by the Institutional Ethics Committee for Human Research (IECHR), Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda. The study has been allotted the ethical approval number IECHR/FCSc/M.Sc./10/2024/44.

Komal

Prof. Komal Chauhan
Member Secretary
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Prof. Mini Sheth
Chairperson
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Chair Person
IECHR
Faculty of Family & Community Sciences
The Maharaja Sayajirao University of Baroda

ANNEXURE II

DETAILS OF CO-ROTATING TWIN SCREW EXTRUDER

Extruder Machine

The extruder used for this experiment was laboratory Co-Rotating Twin-Screw Extruder (Basic Technology Pvt. Ltd (BTPL lab model) made, Model EB-10).

Components and Features of Extruder Machine

Component	Description
Material of Construction	Stainless steel for hygiene purposes
Drive System	Main drive: 7.5 HP variable speed motor (440 V, 3 phase, 50 Hz) with Siemens/ABB frequency drive. Torque limiter coupling on output shaft of worm-reduction gear.
Extruder Barrel	Two parallel co-rotating intermeshing screws, driven by drive assembly. Self-cleaning due to rotation in the same direction.
Feeder	Co-rotating feeder with Siemens Frequency Controller variable speed. Rated capacity controlled by knob on control panel. Calibration chart for feed rate.
Heating Arrangement	Three electric heaters at feeding, kneading, and die sections. Temperature sensors connected to temperature controller on control panel.

Extruder Die	Die plate fixed with a screwed nut. Opening size fixed at 3 mm.
Cutting Knife	Automatic cutting knife driven by variable speed AC motor controlled by frequency controller. Safety guard provided.
Panel Board	Stand-alone control panel displaying screw speed, barrel temperature, feed rate, feed temperature, and cutter rpm.
Water Circulation	Water jacket connected to extruder barrel for cooling. Circulation starts when heater temperature exceeds set limit.
Inching	Bypass switch provided for direct motor drive application for cleaning purposes. Dies must be removed before using inching device.
Emergency Stop	Emergency stop switch on control panel for immediate shutdown in case of foreign object entry into the barrel. Red color for visibility.

Operational Parameters for Crispies Production Using Twin Screw Extruder

Parameters	Specifications
Barrel Temperature	110^{O}C
Extruder screw speed	350 rpm
Feeder speed	12 rpm
Cutter speed	2629 rpm
Torque	10.68
Diameter of the die	3 mm

The DPPH (2,2-diphenyl-1- picrylhydrazyl)

The DPPH (2,2-diphenyl-1- picrylhydrazyl) free radical method is an antioxidant assay based on electron transfer that produces a violet solution in methanol. The Electron of the N-atom in DPPH is reduced by receiving the H-atom from antioxidants. This free radical is stable at room temperature which is reduced in the presence of an antioxidant molecules, producing a colourless methanolic solution.

$$\underset{\textbf{(Purple)}}{\textbf{DPPH + (H—A)}} \longrightarrow \underset{\textbf{(colourless)}}{\textbf{DPPH—H + (A)}}$$

Percent Radical Scavenging Activity can be calculated using the following formula:

% RSA = [(Absorbance of Control − Absorbance of Sample) / Absorbance of Control] × 100

- Concentration of standard: 1mg/ml
- Range of Standard: 1-20 ug/ul
- DPPH concentration: 0.1 mM

The extent of antioxidant activity is quantified by calculating the percentage of radical scavenging activity (% RSA) using the formula:

Pre-Preparation: Acid hydrolysis of *Smurfies* was performed to convert glycosides into aglycones and enhance antioxidant activity prior to DPPH analysis. A homogenized sample in 75% ethanol was treated with 0.6 M HCl, refluxed at 80 °C for 2 hours, neutralized with NaOH, filtered, and stored at −80 °C for further analysis (Li et al., 2020; Tu et al., 2017; Vargas-Leon ́ et al., 2018).

For the assay, the standard was prepared at a concentration of 1 mg/mL, with a working range of 1–20 µg/µL, and the DPPH solution was maintained at a concentration of 0.1 mM. Incubate at room temperature in the dark for 30 minutes and absorbance was taken at 517nm. Table 3.2.1.3.1 shows the protocol for the DPPH Assay.

Protocol for DPPH assay

Tubes	**Methanol (ul)**	**Standard/Sample (ug/ul)**	**DPPH (ul)**
BLANK	2000	-	1000
Control	1000	-	1000
S1	998	2	1000
S2	996	4	1000
S3	994	6	1000
S4	992	8	1000
S5	990	10	1000
S6	988	12	1000
S7	985	15	1000
S8	980	20	1000

Incubate at room temperature in the dark for 30 minutes and absorbance was taken at 517nm.

APPENDIX- IV

CONSENT FORM FOR DETERMINING GLYCEMIC INDEX

STUDY TITLE

Development and Characterization of Smurfies: A Blue Pea Flower (Clitoria ternatea) Powder - Enriched Extruded Millet and Milk-Protein based Breakfast Cereal

I______________________________ have been fully informed about the purpose of the study titled **"Development and Characterization of Smurfies: A Blue Pea Flower (Clitoria ternatea) Powder - Enriched Extruded Millet and Milk-Protein based Breakfast Cereal"**

I have understood the implications of the study and I am willing to participate in the study.

Following biochemical estimations will be done under this study:

1. Blood Haemoglobin
2. Fasting Blood Glucose
3. Oral Glucose Tolerance Test

Protocol for the study:

1. Blood will be drawn once in fasting state.
2. The blood will be drawn by experienced lab technician.
3. Disposable syringes and needles will be used.

The information that is collected will be kept confidential and no personal information will be revealed to anyone. No remuneration will be provided to the participants for being part of the study.

______________________	__________________________
Signature of Investigator	Signature of Participant
Ms. Hetvi Salunke	Contact No.______________
(Researcher)	
Contact No: 7600054624	

____

Signature of Investigator
Ms. Kanchi Baria
(Guide)
Contact No. 7228821182

- Avoid all foods and beverages at least 12 hours before the study visit and avoid vigorous exercise on the morning of the visit.
- Provide a fasting blood sample taken by a finger prick.
- Consume a specified portion of the reference or test food within 15 min.
- Provide a finger prick blood sample at 15, 30, 45, 60, 90 and 120 minutes after beginning to eat the food.

COSTS

This study only requires your time and cooperation. All the cost incurred will be borne by the researcher and there will be no financial compensation for your participation in this research.

POSSIBLE BENEFITS AND RISKS

This study will help to increase scientific knowledge about glycaemic index of Smurfies incorporated recipes. The risk of participation in this study is minimal as only disposable lancets, needles and syringes will be used for drawing blood and it will be done by a trained and authorized technician.

CONFIDENTIALITY

In this study your identity will be kept confidential. The results of the study. Including laboratory or any other data may be published for scientific purposes but will not reveal your name or include any identifiable references to you

RIGHT TO WITHDRAW

Your decision to join the study is voluntary. You may quit at any time, for any reason, without notice. We hope you will take part for the entire study period because we need all the information to draw correct conclusions.

VOLUNTARY CONSENT

Your cooperation is important for the success of this study. Unless many volunteers like you participating in this study it will not be possible. In order to be valid for this study, you should not join other health studies where you would be assigned to receive any medications, special test or treatment.

AVAILABILITY OF RESULTS AND CONSULTATIONS

A copy of the report will be provided to you for future use. If any abnormality is seen in the biochemical profile, you would be advised to contact your doctor. If you have any questions about any part of the study or your rights as a volunteer, you can contact the investigators.

Questionnaire for personal information

Greetings!
Myself, Hetvi Salunke, am currently pursuing a Sr. M.Sc. in Dietetics from the Department of Foods and Nutrition from the Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda. As a part of my MSc dissertation, I am here to gather some personal information for my Glycemic Index study.
I assure you that your responses will be kept confidential. I request your few moments to fill up the form below.

* Indicates required question

1. Name *

2. Date of Birth: *

Example: January 7, 2019

3. Age *

4. Gender *

Mark only one oval.

- Female
- Male
- Prefer not to say

5. Address

6. Contact Number *

7. Religion *

Mark only one oval.

- Hindu
- Muslim
- Jain
- Sikh
- Christian
- Other

8. Marital Status *

Mark only one oval.

- Unmarried
- Married
- Divorced

9. Educational Level *

Mark only one oval.

- Primary
- Secondary
- Higher secondary
- Under-Graduate
- Graduate
- Post- Graduate
- Other: ______________________

10. Occupation *

Mark only one oval.

- Student
- Service
- Business
- Housewife
- Self- employed
- Un-employed
- Other: ______________________

11. Type of Family *

Mark only one oval.

- Nuclear
- Joint
- Extended

12. Number of family member *

Mark only one oval.

- 2
- 3
- 4
- 5
- more than 5

13. Total family Income (Monthly) *

____

14. Per capita income *

____

15. Dietary Habits: *
Type of Diet

Mark only one oval.

- Vegetarian
- Non- vegetarian
- Ovo- vegetarian
- Vegan
- Other: _______________

16. How many meals you consume on regular basis? *

Check all that apply.

- [ ] Breakfast
- [ ] Brunch
- [ ] Lunch
- [ ] Evening snacks
- [ ] Dinner
- [ ] Bed-time

17. Are you suffering from any of the following diseases or conditions? *

Check all that apply.

- [ ] Hypertension
- [ ] Diabetes
- [ ] Dyslipidemia
- [ ] hyper or hypothyroidism
- [ ] No
- [ ] Other: ______________________

18. Kindly, please fill the details on Family history *
Anyone suffering from Obesity

Check all that apply.

- [ ] Mother
- [ ] Father
- [ ] Sibling 1
- [ ] Sibling 2
- [ ] Sibling 3
- [ ] Grandparents
- [ ] No
- [ ] Other: ______________________

19. Anyone suffering from Diabetes *

Check all that apply.

- [ ] Mother
- [ ] Father
- [ ] Sibling 1
- [ ] Sibling 2
- [ ] Sibling 3
- [ ] Grandparents
- [ ] No
- [ ] Other: ____________________

20. Anyone suffering from Hypertension *

Check all that apply.

- [ ] Mother
- [ ] Father
- [ ] Sibling 1
- [ ] Sibling 2
- [ ] Sibling 3
- [ ] Grandparents
- [ ] No
- [ ] Other: ____________________

21. Anyone suffering from cardiovascular Diseases *

Check all that apply.

- [ ] Mother
- [ ] Father
- [ ] Sibling 1
- [ ] Sibling 2
- [ ] Sibling 3
- [ ] Grandparents
- [ ] No
- [ ] Other: ____________________

22. Anyone suffering from hyperlipidemia (abnormal lipid levels) *

Check all that apply.

- [ ] Mother
- [ ] Father
- [ ] Sibling 1
- [ ] Sibling 2
- [ ] Sibling 3
- [ ] Grandparents
- [ ] No
- [ ] Other: ____________________

23. Anyone had a Stroke *

Check all that apply.

- [ ] Mother
- [ ] Father
- [ ] Sibling 1
- [ ] Sibling 2
- [ ] Sibling 3
- [ ] Grandparents
- [ ] No
- [ ] Other: ____________________

24. Anyone suffering from Thyroid *

Check all that apply.

- [ ] Mother
- [ ] Father
- [ ] Sibling 1
- [ ] Sibling 2
- [ ] Sibling 3
- [ ] Grandparents
- [ ] No
- [ ] Other: ____________________

25. Anyone suffering from Cancer *

Check all that apply.

- [ ] Mother
- [ ] Father
- [ ] Sibling 1
- [ ] Sibling 2
- [ ] Sibling 3
- [ ] Grandparents
- [ ] No
- [ ] Other: ____________________

26. Anyone having Asthama? *

Check all that apply.

- [ ] Mother
- [ ] Father
- [ ] Sibling 1
- [ ] Sibling 2
- [ ] Sibling 3
- [ ] Grandparents
- [ ] No
- [ ] Other: ____________________

27. Anyone suffering from any other condition (also specify family member) *

____

28. Is there any sudden weight loss/gain (>5 kg) for the last year? *

Mark only one oval.

- ( ) No
- ( ) Yes
- ( ) Maybe

29. History of any kind of allergy with medicinal or edible plants *

Mark only one oval.

- Yes
- No
- Maybe

30. Are you currently taking any medications? *

Mark only one oval.

- Yes
- No

31. If yes, please mention: Name of the drug, Dosage, Frequency, Date started *

____

32. Any kind of nutritional supplements taken for the last 4 weeks? *

Mark only one oval.

- Yes
- No
- Maybe

33. If yes, please mention: Name of supplement, Dosage, Frequency *

____

34. Lifestyle information: *
Habitual Profile-
Tea

Mark only one oval.

- Taking currently
- Past Habit
- No

35. Coffee or Bidi *

Mark only one oval.

- Taking currently
- Past habit
- No

36. Tobacco or Gutka *

Mark only one oval.

- Taking currently
- Past habits
- No

37. Smoking *

Mark only one oval.

- Taking currently
- Past habits
- No

38. Alcohol *

Mark only one oval.

- Taking currently
- Past habits
- No

39. Anropometry Measurement:
Weight (in Kg)

40. Height (in cm)

41. BMI

42. Waist circumference (in cm)

43. Hip circumference (in cm)

44. Waist hip ratio

Google Forms

APPENDIX-VII

CONSENT FORM FOR SENSORY EVALUATION

STUDY TITLE

Development and Characterization of Smurfies: A Blue Pea Flower (*Clitoria ternatea*) Powder - Enriched Extruded Millet and Milk-Protein based Breakfast Cereal

INVESTIGATORS

Ms. Kanchi Baria
Assistant Professor
Department of Foods and Nutrition
Faculty of Family and Community sciences
The Maharaja Sayajirao University of Baroda, Vadodara
Mobile No: 7228821182

Ms. Hetvi Salunke
Senior Masters Dietetics
Department of Foods and Nutrition
Faculty of Family and Community Sciences
The Maharaja Sayajirao University of Baroda. Vadodara
Mobile No: 7600054624

PURPOSE OF STUDY

The purpose of this study is to develop a Blue Pea-Incorporated Millet and Milk Protein-Based Extruded Breakfast Cereal that offers a nutritious, convenient, and sustainable breakfast option for modern consumers. This cereal combines the health benefits of antioxidants, fiber and high-quality protein. Additionally, this research aligns with India's initiatives to promote self-reliance and environmental sustainability by utilizing locally sourced, drought-resistant crops like millets and blue pea flower. Your participation in this study will help assess the product's sensory appeal and overall acceptability, contributing to the development of a healthier, more sustainable food option.

PROTOCOL OF THE STUDY

If you decide to join this study you will be required to taste Smurfies incorporated recipes and carry out the sensory evaluation of the recipes, using the hedonic rating scale and composite rating scale. 6 different recipes will be incorporated with Smurfies, sensory evaluation of which will be carried out on 10 different days.

COSTS

This study only requires your time and co-operation. All the costs incurred will be borne by the researcher and there is no financial compensation for your participation in this research.

POSSIBLE BENEFITS AND RISKS

This study will help to increase scientific knowledge about the taste and overly acceptability of Smurfies incorporated recipes. The risk of participation in this study is minimal.

CONFIDENTIALITY

In the study your identity will be kept confidential. The results of the study may be published for scientific purposes but will not reveal your name or include any identifiable references to you.

RIGHT TO WITHDRAW

Your decision to join the study is voluntary. You may quit at any time, for any reason, without notice. We hope you will take part for the entire study period because we need all the information to draw correct conclusions.

VOLUNTARY CONSENT

Your co-operation is important for the success of this study. Unless many volunteers like you participate in this study it will not be possible. In order for this study to be valid, you should not join other health studies where you would be assigned to receive any medication, special test or special treatment

INVESTIGATOR'S STATEMENT

I have explained the research program, purpose of the study and possible benefits and risks of participating in the study. The participating was given an opportunity to discuss the procedures and to ask any additional questions.

__________________________ __________________________

Signature of the Investigator	Signature of the Investigator
Ms. Hetvi Salunke	Ms. Kanchi Baria

PARTICIPANT'S STATEMENT

I certify that I have read, or had read out to me, and that I have understood the description of the study. By signing this form, I am attesting that I have read and understood the information given above. I give my consent to be included as a subject in the study being carried out by Ms. Kanchi Baria and Ms. Hetvi Salunke of The Maharaja Sayajirao University of Baroda to determine the acceptability of Smurfies incorporated recipes.

I understand that the study requires the participant to taste Smurfies incorporated recipes. I have had a chance to ask questions about the study. I understand that may ask further questions at any time I have been explained to my satisfaction the purpose of this study any time

PARTICIPANT'S NAME____

SIGNATURE____________________

DATE______________

APPENDIX VIII

SENSORY EVALUATION OF THE RECIPES

9 POINT HEDONIC RATING SCALE

Title- Development and Characterization of Smurfies: A Blue Pea Flower (Clitoria Ternatea) Powder -Enriched Extruded Millet and Milk-Protein based Breakfast Cereal

Name:

Product name:

Date:

Taste the food samples and rate the samples for their acceptability as per the 9-point scale given below.

Points	**Degree of Preference**	**Sample A**	**Sample B**	**Sample C**
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			

Comments and suggestions:

Signature:

APPENDIX IX

SENSORY EVALUATION OF THE RECIPES

COMPOSITE RATING SCALE

Title- Development and Characterization of Smurfies: A Blue Pea Flower (Clitoria Ternatea) Powder -Enriched Extruded Millet and Milk-Protein based Breakfast Cereal

Name:

Product:

Date:

Taste the sample and rate the sample for their sensory attributes as per the maximum scores given below:

Attributes	Maximum score	Sample A	Sample B	Sample C
Colour and Appearance	20			
Flavour	15			
Taste	15			
Texture	20			
Mouthfeel	10			
After taste	10			
Overall Acceptability	10			
Total Score	100			

Comment and Suggestion:

Signature:

APPENDIX-IX

QUESTIONNAIRE- SEMI TRAINED PANEL- RECIPES

Title- Development and Characterization of Smurfies: A Blue Pea Flower (Clitoria Ternatea) Powder -Enriched Extruded Millet and Milk-Protein based Breakfast Cereal

Section 1: Demographics

1. **Name:**
2. **Gender:** ◯ **Male** ◯ **Female** ◯ **Others**
3. **Occupation:**
4. **Date of Birth:**
5. **Age:**
6. **Phone Number:**
7. **Email address:**

8. **Do you regularly consume breakfast cereals?**
   - o Yes
   - o No
9. **How many times a week do you eat breakfast cereals?**
   - o 1-2
   - o 3-4
   - o 5 or more

Section 2: Health and Nutritional Perception

10. **How healthy do you think this cereal is compared to your regular breakfast cereal?**
    - o Much healthier
    - o Somewhat healthier
    - o About the same
    - o Less healthy
11. **Do you think the inclusion of Blue Pea Flower and Millets makes this cereal more nutritious?**
    - o Yes
    - o No
    - o Not sure

12. **Are you aware of the antioxidant benefits of Blue Pea Flower?**

   - o Yes
   - o No

13. **Would you consider switching to a cereal that contains millet and Blue Pea Flower for its nutritional benefits?**

   - o Yes
   - o No
   - o Maybe (Please specify any concerns) _____________

14. **How important is it to you that the cereal is high in protein (from milk proteins like whey)?**

   - o Very important
   - o Somewhat important
   - o Not important

<u>Section 3: Sustainability and Local Sourcing</u>

15. Does the fact that this cereal uses locally sourced ingredients (millets and blue pea flower) influence your decision to buy it?

   - o Yes, it's important
   - o Maybe, I need more information
   - o No, it doesn't affect my decision

16. How important is it to you that the cereal is made using sustainable ingredients like drought-resistant millets?

   - o Very important
   - o Somewhat important
   - o Not important

17. Would you pay more for a cereal that promotes sustainability and uses local ingredients?

- Yes
- No
- Maybe (Please specify how much more you'd be willing to pay) ____________

18. **Would you consider incorporating this cereal into your regular breakfast routine?**

- Yes
- No
- Maybe

19. **What do you like most about the cereal?**

- Taste
- Texture
- Nutritional benefits
- Sustainability aspect
- Other (please specify) _____________

20. **Any additional comments or feedback on the product?**

____

____

____

____

____

Thank You

APPENDIX-V

PARTICIPANT INFORMATION SHEET

Development and Characterization of Smurfies: A Blue Pea Flower (*Clitoria ternatea*) Powder – Enriched Extruded Millet and Milk-Protein based Breakfast Cereal

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INVESTIGATORS

Ms. Kanchi Baria

Assistant Professor

Department of Foods and Nutrition

Faculty of Family and Community sciences

The Maharaja Sayajirao University of Baroda,

Vadodara

Mobile No: 7228821182

Ms. Hetvi Salunke

Senior Masters Dietetics

Department of Foods and Nutrition

Faculty of Family and Community Sciences

The Maharaja Sayajirao University of Baroda.

Vadodara

Mobile No: 7600054624

PURPOSE OF STUDY

The purpose of this study is to develop a Blue Pea-Incorporated Millet and Milk Protein-Based Extruded Breakfast Cereal that offers a nutritious, convenient, and sustainable breakfast option for modern consumers. This cereal combines the health benefits of antioxidants, fiber and high-quality protein. Additionally, this research aligns with India's initiatives to promote self-reliance and environmental sustainability by utilizing locally sourced, drought-resistant crops like millets and blue pea flower. Your participation in this study will help assess the product's sensory appeal and overall acceptability, contributing to the development of a healthier, more sustainable food option.

PROTOCOL OF THE STUDY

If decide to join this study, information regarding medical history, family history of lifestyle disease etc. will be assessed with the help of questionnaire. Anthropometric measurements i.e. your height, weight, waist circumference and hip circumference will be taken using standard procedures. You are expected to make eleven study visits, each lasting approximately 130 minutes. On three of the study visits you will be asked to consume a reference food i.e., 50g of glucose. On the other eight study visits you will be asked to consume the standard recipe (without Smurfies incorporation), or the test recipes (with Smurfies incorporation) both of which will contain 50g of available carbohydrate and will be tested on separate days Each study visit will include the following procedures:

INVESTIGATOR'S STATEMENT

I have explained the research program, purpose of the study and possible benefits and risk of participating in the study. The participant was given opportunity in discuss the procedures and to ask additional questions.

__________________________ __________________________

Signature of the Investigator	Signature of the Investigator
Ms. Hetvi Salunke	Ms. Kanchi Baria
Date________________	Date ________________

PARTCIPANT'S STATEMENT

I certify that I have read, or had read out to me, and that I have understood the description of the study. By signing this form. I am attesting that I have read and understood the information given above. I give my consent to be included as the subject in the study being carried out by Ms. Kanchi Baria and Ms. Hetvi Salunke The Maharaja Sayajirao University of Baroda to investigate the glycaemic index of Smurfies incorporated recipes.

I understand that the study requires the participants to consume equicarbohydrate recipes. It also requires the participate to give blood samples to measure various parameters. I have had a chance to ask questions about the study. I understand that I may ask further questions at any time. I have been explained to my satisfaction the purpose of this study and I am also aware of my right to opt out of the study any time.

PARTICIPANT'S NAME____

SIGNATURE_____________________

DATE_______________