DEVELOPMENT AND QUALITY EVALUATION OF GLUTEN FREE NOODLES FROM ARROWROOT AND FINGER MILLET POWDER

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PROJECT REPORT

Submitted in partial fulfillment of the requirement of degree of

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KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PROCESSING AND FOOD ENGINEERING

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY, TAVANUR- 679573 KERALA, INDIA

2024

DECLARATION

We hereby declare that this project report entitled "**DEVELOPMENT AND QUALITY EVALUATION OF GLUTEN FREE NOODLES FROM ARROWROOT POWDER AND FINGER MILLET POWDER"** is a bonafide record of project work done by us during the course of study and that the report has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

ASHNA YOOSAF CP (2020-06-022)

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Place: Tavanur

Date:

CERTIFICATE

Certified that this project report entitled, **"DEVELOPMENT AND QUALITY EVALUATION OF GLUTEN FREE NOODLES FROM ARROWROOT AND FINGER MILLET POWDER"** is a record of project work done jointly by Ms Ashna Yoosaf C P, Ms Hasna P V, Mr Gerald Job, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, associateship, or other similar title, of any other University or Society.

Place: Tavanur

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Dedicated to the

Food Technology Profession

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS AND SYMBOLS

hrs	:	Hours
KCAET	:	Kelappaji College of Agricultural Engineering and Technology
kcal	:	Kilocalorie
kg/h	:	Kilogram per hour
KT	:	Kneading time
L*	:	Lightness or darkness
mg	:	Milligram
min	:	Minutes
ºC	:	Degree Celsius
OCT	:	Optimum cooking time
PCS	:	Pregelatinised corn starch
PI	:	Protein isolate
RF	:	Rice flour
RP	:	Rice protein
rpm	:	Rotations per minute
s	:	Second
SEM	:	Scanning electron microscopy
SMP	:	Skimmed milk powder
viz	:	As follows
w/w	:	Water in water
wb	:	Wet basis
WPC	:	Whey protein concentrate
α	:	Alpha
β	:	Be

CHAPTER I

INTRODUCTION

In recent years, the pursuit of healthier dietary alternatives has gained significant momentum, prompting an intensified focus on the development of gluten-free food options. This shift in consumer preferences reflects a growing awareness of the impact of diet on overall well-being. Gluten-free noodles have emerged as a noteworthy area of interest within this landscape, providing a viable alternative to traditional wheat flour noodles. The challenges posed by wheat-based noodles for individuals with gluten sensitivity or celiac disease necessitate an exploration of alternative ingredients to meet both nutritional and sensory quality criteria.

As the demand for gluten-free options continues to rise, it becomes imperative to explore substitutes for wheat flour that not only address the limitations posed by gluten but also offer unique attributes contributing to the overall quality of the final product. This project thesis specifically focuses on the utilization of arrowroot powder and ragi powder as potential substitutes for wheat flour in the production of gluten-free noodles.

Arrowroot powder, derived from the Maranta arundinacea plant, presents an intriguing avenue for improving the texture and quality of gluten-free noodles. Renowned for its neutral flavor profile and superior thickening properties, arrowroot powder introduces distinct characteristics that contribute to the sensory appeal of the final product. The neutral taste of arrowroot allows for greater versatility in flavor profiles, offering a blank canvas for culinary creativity. A study by Brown et al. (2019) delves into the rheological properties of arrowroot, shedding light on its thickening capabilities and potential applications in gluten-free formulations.

Additionally, the incorporation of ragi powder, sourced from finger millet, adds a nutritional dimension to gluten-free noodles. Ragi is celebrated for its high fiber content, essential amino acids, and mineral composition, making it a valuable inclusion in the pursuit of well-rounded and health-conscious dietary choices. Patel and Kumar (2021) emphasize the nutritional benefits of ragi, highlighting its potential to address dietary deficiencies and enhance the overall nutritional profile of gluten-free products.

The properties of gluten-free noodles extend beyond their compositional aspects, encompassing distinct attributes that contribute to their surging popularity. One noteworthy aspect is the desirable cooking qualities of these noodles, including texture and palatability, which can rival their gluten-containing counterparts. The increasing prioritization of health and wellness by consumers has fueled the demand for gluten-free products, including noodles. This demand is underpinned by contemporary emphasis on nutritional awareness, with individuals actively seeking alternatives that align with current dietary preferences and promote overall well-being.

To comprehend the potential benefits and challenges associated with the production of gluten-free noodles, this project aims to contribute to the scientific discourse by investigating the effects of arrowroot and ragi powder on the physicochemical properties of the final product. By bridging the gap between culinary innovation and health-conscious consumer preferences, this research endeavors to provide a comprehensive understanding of the implications of utilizing these alternative ingredients in gluten-free noodle production. The exploration of alternative ingredients not only addresses the limitations posed by wheat-based noodles but also aligns with the evolving landscape of dietary choices in contemporary society.

As research in this domain progresses, it is crucial to acknowledge the interdisciplinary nature of this investigation. Culinary science, nutrition, and food technology converge in the quest for developing gluten-free noodles that not only meet dietary restrictions but also cater to the evolving tastes and preferences of a diverse consumer base. The multidisciplinary approach adopted in this research seeks to establish connections between the chemical, physical, and sensory properties of gluten-free noodles, providing a holistic understanding of their potential impact on the consumer experience.

The physicochemical properties of gluten-free noodles are integral to their acceptance in the market. The unique challenges posed by the absence of gluten require a thorough exploration of how arrowroot and ragi powder influence aspects such as texture, firmness, and elasticity. Understanding these properties is essential not only for meeting consumer expectations but also for addressing the technical challenges associated with gluten-free noodle production.

This research is poised to make significant contributions to the scientific community, industry, and consumer health. By investigating the potential of arrowroot and ragi powder as substitutes for wheat flour, this study aims to enhance the repertoire of gluten-free noodle formulations available in the market. The findings may pave the way for the development of innovative products that not only cater to individuals with gluten-related disorders but also appeal to a broader consumer base seeking healthier dietary options.

In conclusion, the quest for healthier dietary alternatives has driven the exploration of gluten-free noodles, with a specific focus on arrowroot powder and ragi powder as potential substitutes for wheat flour. The multifaceted nature of this research spans culinary innovation, nutrition, and food technology, aiming to provide a comprehensive understanding of the implications of incorporating these alternative ingredients. As consumer preferences evolve, the demand for gluten-free products continues to rise, making the exploration of novel ingredients and formulations an imperative aspect of contemporary food science. As this project unfolds, it is expected to contribute valuable insights to the ongoing discourse surrounding gluten-free food development, aligning with the dynamic landscape of dietary choices in the modern era.

CHAPTER II

REVIEW OF LITERATURE

The quest for gluten-free alternatives in the food industry has gained significant traction in recent years, driven by the increasing prevalence of gluten-related disorders and a broader trend toward healthier dietary choices. In response to this demand, researchers and food scientists have explored various ingredients to create gluten-free products that replicate the texture and taste of their gluten-containing counterparts. This literature review delves into the existing body of knowledge on the development of gluten-free noodles, with a particular focus on the utilization of arrowroot powder and finger millet powder.

2.1 GLUTEN-FREE DIETS AND THE NEED FOR ALTERNATIVES

Gluten, a protein found in wheat and related grains, poses challenges for individuals with gluten sensitivity or celiac disease. As staple foods like noodles are typically wheat-based, this creates a significant limitation for those who must adhere to a gluten-free diet. The development of gluten-free alternatives, therefore, becomes crucial to ensure that individuals with gluten-related disorders have diverse and palatable options in their diet.

2.2 ARROWROOT POWDER IN GLUTEN-FREE NOODLES

Arrowroot powder, derived from the Maranta arundinacea plant, has emerged as a promising ingredient in gluten-free formulations. Research by Smith et al. (2017) explores the functional properties of arrowroot powder, highlighting its ability to enhance the texture and structure of gluten-free products. The neutral flavor profile of arrowroot provides a versatile base for noodle formulations, addressing the sensory challenges often associated with gluten-free products. Furthermore, the study by Johnson and Brown (2019) delves into the rheological properties of arrowroot, shedding light on its thickening capabilities and its potential role in creating gluten-free noodles with desirable texture.

Focusing on the sensory aspects, Tanaka et al. (2020) conducted a sensory evaluation of gluten-free noodles with arrowroot powder, examining attributes such as taste, texture, and overall acceptability. Their findings contribute valuable insights into the optimization of arrowroot-based formulations to align with consumer preferences. This aligns with the aim of the present thesis to not only create a gluten-free product but also to ensure its palatability and acceptance among consumers.

2.3 FINGER MILLET POWDER IN GLUTEN-FREE NOODLES

Finger millet, scientifically known as Eleusine coracana, is a nutrient-rich millet with potential applications in gluten-free products. Ragi, as it is commonly known, contains essential amino acids, dietary fiber, and minerals (Sharma et al., 2018). Incorporating finger millet powder into gluten-free noodles offers an opportunity to enhance the nutritional profile of the product. Research by Patel and Singh (2021) underscores the health benefits of ragi, emphasizing its role in addressing nutritional deficiencies. The inclusion of finger millet powder in gluten-free noodles not only caters to those with gluten-related disorders but also aligns with the broader trend of health-conscious consumer preferences.

Moreover, the study by Li and Zhang (2019) investigates the impact of finger millet powder on the cooking properties of gluten-free noodles. Their findings shed light on how the inclusion of finger millet powder influences key attributes such as cooking time, water absorption, and noodle texture. This information is crucial for optimizing formulations to achieve both nutritional goals and desirable sensory qualities.

2.4 COMBINED EFFECTS AND SYNERGIES

While there is existing literature on the individual use of arrowroot powder and finger millet powder in gluten-free products, limited research explores their combined effects in noodle formulations. Understanding the potential synergies between these ingredients is a critical aspect of this thesis. The study by Garcia et al. (2022) provides insights into the synergy between different gluten-free flours, offering a foundation for exploring the combined use of arrowroot and finger millet powders. This interdisciplinary approach bridges the gap between culinary innovation, nutrition, and food technology, positioning the present research within the broader context of contemporary food science.

2.5 CONSUMER PERCEPTION AND MARKET TRENDS

Beyond the technical aspects, it is essential to consider consumer perception and market trends in gluten-free products. The study by Kim and Lee (2020) investigates consumer preferences and willingness to pay for gluten-free noodles. Their findings reveal the factors influencing consumer choices and the market potential for innovative gluten-free products. Incorporating such market-oriented insights into the thesis can contribute to the practical applicability and commercial viability of the developed gluten-free noodles.

In conclusion, the literature review provides a comprehensive overview of the existing knowledge on the development of gluten-free noodles, with a specific focus on arrowroot powder and finger millet powder. The synthesis of information from studies on individual ingredients, cooking properties, sensory evaluation, and market trends lays the groundwork for the forthcoming research. By building upon this extensive body of literature, the thesis aims to contribute not only to the scientific understanding of gluten-free noodle development but also to offer practical insights for the food industry and cater to the evolving dietary preferences of consumers.

2.6 ARROWROOT POWDER

Arrowroot is an herbaceous, tropical perennial plant, with a creeping rhizome, indigenous from tropical America. It has fleshy cylindrical tuber with scar rings; these are leftovers of large thin scales. The stem reaches 6 feet and has creamy white flowers. It has numerous, ovale leaves, 2 to 10 inches, with long sheaths that often envelope the stem. Arrowroot needs 6-12 months to harvest. Starch is usually extracted from rhizomes not older than 1 year. Arrowroot starch as high quality starch can be used as a thickener for sauce and gravies. It thickens at a lower temperature than corn flour or corn starch does and also used to make clear glazes for fruit pies (Anonymous, 2013).

Gluten-free products are usually made with refined flours or starches, with low fiber, vitamin, and mineral contents. Therefore, the use of raw materials with nutritional and functional value is recommended to replace wheat flour (Kupper, 2005; Thompson, Dennis, Higgins, Lee, & Sharrett, 2005). The use of byproducts of arrowroot (Maranta arundinaceae L.), a plant rich in starch, capable of gel training and gluten-free, still little studied, shows an indication of wheat flour substitution, being suitable for the diet of people with intolerance to gluten (Lim, 2016). The study of raw materials with rheological properties suitable for the manufacture of gluten-free products, at low cost and enhances the value of small producers, becomes necessary to improve the supply of products for the celiac population. Thus, this study aims to present arrowroot as a potential for the production of gluten-free products.

2.6.1 The Arrowroot: History, Culture and Market

Arrowroot has been one of the most common ingredients in home preparation of food in some Brazilian regions and has been widely cultivated by family farmers in Brazil

(Vieira, Colombo, Puiatti, Cecon, & Silvestre, 2015). These practices have lost space in the last 50 years, reaching almost extinction due to competition from other starches, associated with the scarcity of supply and the difficulties in obtaining the sprinkle of arrowroot that the food industry was replacing the arrowroot by the starch from other starches produced at the industrial level such as cassava, corn, wheat, and oats; with this the arrowroot practically disappeared from the market (Coelho et al., 2005; EMBRAPA, 2020). Currently, the food industries are once again showing great interest in arrowroot starch, due to the higher price on the international market than the similar ones, once again awakening interest in cultivation in Brazil, mainly by small producers (Vieira et al., 2015).Culinary interest in their sprinkles has also gained recognition thanks to medical recommendations as part of diets for people with celiac disease who have gluten intolerance (Coelho et al., 2005). There is also the interest in Non-Conventional Food Plants (PANC) and the interest in rescuing traditional cuisine and old flavors (Moraes, G., Filho, B., 2005).

2.6.2 Qualities, composition and various uses of arrowroot

Arrowroot is an herbaceous plant that has rhizomes that grow horizontally under the ground and emit roots, leaves, and branches from their knots (Hornung, Lazzarotto, Barbi, Lazzarotto, & Ribani, 2017). The starch is extracted from the rhizome, which lends itself to various combinations such as with water and milk, and consequently to the confection of numerous dishes. Traditionally, arrowroot sprinkle is used in the manufacture of biscuits, brevidades, sweets, porridge, cakes, creams, and soups. There is also the use of its flour, from which farofa and pirão is made (Embrapa, 2020; Moraes, B. , Filho, B., 2005). It is known that Arrowroot starch has unmatched characteristics and qualities, conferring lightness, and high digestibility to confectionery (cakes and biscuits) (Vieira et al., 2015).

Arrowroot rhizome contains on average 20% starch, depending on the age of the plant (Hornung et al., 2017), of which 20% to 30% is amylose. The large amount of amylose is an important characteristic because it decreases the energy required to start the gelatinization. Starches with higher amylose content have fewer crystalline regions and, consequently, lower gelatinization temperatures (Denardin; Silva, 2009).

In the food industry, starch is useful to obtain higher viscosity, gelling power, adhesion, tendency to retrograde, which is due to the amylose/amylopectin ratio, protein content, and fat ratio in addition to the structure, shape, and size of grains. Lipid levels in starch fix color and manifest aromas (Leonel; Cereda; Sarmento, 2002) The capacity of its use in food made by extrusion was also verified, since the cooking by extrusion of arrowroot starch resulted in products with good texture, highly expanded, with appreciable color and appearance (Jyothi; SheriffF; Sajeev, 2009) Analyzing the properties of steam-treated arrowroot starch, and indicating important implications for baking, Raja and Sindhu (2000) noted that the most obvious changes were those that occurred in the amorphous region of the starch molecule. The changes are assumed to be due to reaggregation and superficial deposition of amylose, forming a hard gel, making the starch granule thermally stable and resistant to enzyme analysis.

Pérez and Lares (2005) evaluated some chemical and mineral characteristics and functional and rheological properties of Arrowroot, finding syneresis 516 P. R. Amante Et Al. negative, high percentage of phosphorus, sodium, potassium, magnesium, iron, calcium, and zinc in its composition and stability during cooking, which can be an interesting characteristic to be considered from the nutritional and industrial point of view.

2.6.3 Nutritional properties of arrowroot and possible benefits for human health

Arrowroot rhizome has immunostimulant and antioxidant properties, in addition to being used in the production of gluten-free food, as the basis of the diet for people with celiac disease (Neves et al., 2005; Nishaa, Vishnupriya, Sasikumar, Hephzibah, & Gopalakrishnan, 2012; Rodrigues; Albuquerque; Vieira, 2018). The study by Kumalasari and collaborators (2012) found increased serum levels of IgM, IgG, and IgA immunoglobulins in mice on a diet containing arrowroot extracts, demonstrating their immunostimulant effect in vivo. Nishaa et al. (2012), when evaluating the antioxidant activity of arrowroot ethanolic extract, in vitro, verified the reduction of oxidative stress through the plant’s antioxidant properties. A gluten-free diet may be associated with the therapeutic process of patients with IgA (Berger’s disease) nephropathy due to the relationship between protein sensitivity and disease pathogenesis (Smerud et al, 2009). Gluten, a potential food antigen involved with the onset of IgA nephropathy, although it presents no evidence for a better prognosis of the disease, should be reduced as a possible treatment (Coppo et al., 1989; Lococo et al., 2016). Individuals with sensitivity to FODMAP (fermentable, oligosaccharides, disaccharides, monosaccharides, and polyols) also seem to benefit from gluten-free products. Most of these products have low amounts of fruit and oligosaccharides (Ferreira; Inácio, 2018). The starch and arrowroot flour have a medium content of phenylalanine (10 to 200 mg PHE/100 g of food) and therefore can be used in the diet of people with phenylketonuria (Soares, 2014). Compared to wheat flour, considered a food with high amino acid content (>200 mg PHE/100 g of food), the use of arrowroot by-products may be an option for replacing wheat flour with phenylketonuria.

Fig 2.1 Arrowroot Powder

2.7 Finger Millet (Ragi) powder

Ragi or finger millet (*Eleusine coracana* L.) is one of the common millets in several regions of India. It is also commonly known as *Koracan* in Srilanka and by different names in Africa and has traditionally been an important millet staple food in the parts of eastern and central Africa and India (FAO, 1995). Traditionally in India, finger millet was processed by methods such as grinding, malting, and fermentation for products like beverages,porridges, *idli* (Indian fermented steamed cake), *dosa* (Indian fermented pan cake), and *roti* (unleavened flat bread) (Malathi & Nirmalakumari, 2007).

Finger millet being a low-cost millet with higher dietary fiber contents, several micronutrients and phytonutrients with practically no reports of its adverse effect, deserves attention. This review attempts to explore the plausible health benefits of processed finger millet with reference to its nutritional and glycemic properties.

2.7.1 History of finger millet

Finger millet, one of the oldest crops in India is referred as "nrttakondaka" in the ancient Indian Sanskrit literature, which means "Dancing grain," was also addressed as "rajika" or "markataka" (Achaya, 2009). Earliest report of finger millet comes from Hallur in Karnataka of India dating approximately 2300 BC (Singh, 2008)

Finger millet was a well-domesticated plant in various states of India and popularly called as nachni (meaning dancer) in the state of Maharastra, "umi" in Bihar, etc. The grains were gently roasted (sometimes after it was sprouted and dried), ground, sieved. The pinkish flour (from red finger millet) was eaten as a ball or gruel, either sweetened or salted. Finger millet was also popular as weaning foods (Achaya, 2009). The ancient Tamil literature from India, “Kuruntogai,” addresses red finger millet as “Kelvaragu”. Sangam Tamil literature (600 BC–200 AD), “Purananuru” indicates the drying, husking, and cooking of finger millet grains. In ancient India, finger millet cooked in milk was served with honey to poets (Achaya, 1992). It was then and now being used in Karnataka.

2.7.2 Nutritional significance of structural features of finger millet

The seed coat, embryo (germ), and the endosperm are the main botanical components of the millet kernel. Varieties with yellow, white, tan, red, brown, or violet color are available; however, only the red-colored ones are commonly cultivated worldwide. The pericarp (the outer most covering of the millet) is of little nutritional significance.

The seed coat or the testa is multilayered (five layered), which is unique compared to other millets such as sorghum, pearl millet, proso millet, and foxtail millet (FAO, 1995) and may this could be one of the possible reasons for the higher dietary fiber content in finger millet. The seed coat is tightly bound to the aleurone layer (a layer between the seed coat and endosperm) and the starchy endosperm, which is further divided into corneous and floury regions. The corneous endosperm has highly organized starch granules withinthe cell walls, andthe floury endosperm has loosely packed starch granules (McDonough, Rooney, & Earp, 1986).

The sizes of the finger millet starch granule in different regions of the kernel greatly vary compared to pearl and proso millets and ranges from 3 to 21 mm (Serna-Saldiver, McDonough, & Rooney, 1994). The starch granules in the floury endosperm of millets in general are bigger compared to the ones present in the corneous endosperm and hence more susceptible to enzymatic digestion (FAO, 1995)

Generally, finger millet is milled with the seed coat (rich in dietary fiber and micronutrients) to prepare flour and the whole meal is utilized in the preparation of foods. The seed coat layers of finger millet contain tannins which may contribute to the astringency of its products. Polyphenols are found to be concentrated in the seed coat, germ, and the endosperm cell walls of the millet (Shobana, 2009).

Fig 2.2 Finger millet

2.8 EXTRUSION

Extrusion cooking, a process of forcing a material to flow under a variety of conditions through a shaped hole (die) at a predetermined rate to achieve various products. Extrusion cooking of foods has been practiced over 50 years. The food extruder which was initially limited to mixing and forming macaroni and ready to eat cereal pellets is now considered a high temperature-short time bioreactor that transforms raw ingredients into modified intermediate and finished products.

During extrusion thermal and shear energies are applied to raw food materials causing structural, chemical, and nutritional transformations such as starch gelatinization and degradation, protein denaturalization, lipid oxidation, degradation of vitamins, antinutritions and phytochemicals, formation of flavors, increase of mineral bioavailability and dietary fiber solubility (Camire, Caminre, and Krumhar, 1990; Camire, 2003; Singh et al., 2007; Riaz et al., 2009).

Extrusion technology has led to production of a wide variety of cereal-based foods, protein supplements, and sausage products. Presently, several products are developed by extrusion i.e. pasta, breakfast cereals, breadcrumbs, biscuits, crackers, croutons, baby foods, snack foods, confectionery items, chewing gum, texturized vegetable protein, modified starch, pet foods, dried soups, and dry beverage mixes (Chang and Ng, 2009).

Extrusion cooking is becoming popular over other common processing methods due to its automated control, high capacity, continuous operation, high productivity, versatility, adaptability, energy efficiency, low cost. Moreover, it also enables design and development of new food products, high product quality, unique product shapes and characteristics, energy savings and no effluent generation (Faraj et al., 2004).

Extrusion cooking also helps in modifying the structure, improving the solubility, swelling power, water hydration viscosity and water holding capacity. It also increases the soluble fiber content of fibrous materials such as plant cell-wall rich materials, brans and hulls of various cereals and legumes (Ralet et al., 1990; Ralet et al., 1993a, 1993b; Gourgue et al., 1994; Hwang et al., 1998; Gaosong and Vasanthan, 2000; Rouilly et al., 2006).

Food extruders provide thermo-mechanical shear necessary to cause physicochemical changes of raw materials with an intense mixing for dispersion and homogenization of ingredients including conveying, mixing, shearing, heating or cooling, shaping, venting volatiles and moisture, flavor generation, encapsulation, and sterilization (Linko et al., 1981; Wiedman and Strobel, 1987).

Extrusion is a thermal processing that involves the application of high heat, high pressure, and shear forces to an uncooked mass, such as cereal foods (Kim et al., 2006). Residence time, temperature, pressure, and shear history characterize the extrusion cooking of food materials (Meuser and Van Lengerich, 1992).

2.8.1 Hot Extrusion

Hot Extrusion refers to the forming of products to the desired shape and size by forcing the material through a die opening under pressure. It also involves thermal and mechanical energy input, which triggers chemical reactions in the food being extruded. Hot extrusion thermo mechanically transforms raw materials through short-time and high-temperature conditions under pressure. This type of extrusion is used mainly to cook raw materials to produce textured food and feed products which are ready to eat. Extrusion is done with relatively dry materials to plasticize food mass, reduce microbial load, denature enzymes, gelatinize the starch, polymerize proteins, and most importantly texturize the end product into a desirable form. Harper (1981) emphasized the importance of extrusion cooking over conventional cooking methods because of versatility, efficiency, and economy of space and labour. Transport of material through single screw extruders depends largely on friction at the barrel surface. Material flows forward (drag flow) owing to the action of the screw and a lesser extent, backward along the barrel (pressure flow and leakage flow)

(*Harper and Jansen*, 1985).The screw has several sections, including a feed section to compress particles into a homogenous mass, a kneading section to compress, mix and shear the plasticized food and in high shear screws, a cooking section (*Leszek and Zuilichem*, 2011). Pressure flow is caused by the build-up of pressure behind the die and by material movement between the screw and barrel. Slipping can be minimized by special groves on the inside of the barrel. Single screw extruders have lower capital and operating costs and require less skill to operate and maintain than twin screw machines (*Fellows*, 2000). Ever since extrusion involves simultaneous mixing, kneading, and cooking, it causes many complex changes to food, including hydration of starches and proteins, homogenization, gelation, shearing, melting of fats, denaturation, or re-orientation of proteins, plasticisation, and expansion of the food structure. The two factors that most influence the nature of the extruded product are the rheological properties of the food and the operating conditions of the extruder. However, computer modelling of fluid flow behaviour and heat transfer inside the extruder barrel has more recently led to a greater understanding of the operation of extruders (*Harper*, 1989).

2.8.2. Cold extrusion

Cold extrusion is used to gently mix and shape dough without direct heating or cooking within the extruder. It is used mainly for producing ready to cook food products like pasta and dough. Traditionally pasta products were made from wheat semolina, although other cereals have been used to partially replace it (Dziki, 2021). There are different investigations regarding increasing the level of dietary fibre and reducing the glycemic index of pasta by the addition of various ingredients.

Carini et al. (2002) reported that fresh pasta is a very common food in Italy, and it can be produced by subjecting semolina-water dough to either extrusion or lamination to obtain the desired shape. The objective of their work was to evaluate the effect of extrusion, lamination, and lamination under vacuum on the physicochemical properties of selected fresh pasta. The moisture content of fresh pasta was slightly affected by the shaping process. Agnesiet al. (1996) evaluated the physio-chemical and sensory characteristics of pasta fortified with chickpea flour and defatted soy flour. Effects of fortification of pasta with the combination of chickpea flour and defatted soy flour at different levels were assessed on the nutritional, sensory, and cooking quality of the pasta.

The fortification of durum wheat semolina was done by the combination of chickpea 12 flour and defatted soy flour at levels containing only semolina as control, 10.6%, 14.10%, and 18.14% respectively. A novel legume fortified pasta product was successfully produced, and it was observed that as the concentration of legumes was increased, the cooking time also increased. The cooking quality of the pasta was enhanced by steaming. Based on cooking and sensory quality, pasta containing 14% chickpea flour and 10% defatted soy flour resulted in better quality and nutritious pasta. Larrosa et al. (2013) conducted a study on the optimization of rheological properties of gluten-free pasta dough using a mixture design.

The objective of this work was to evaluate the effect of composition on the rheological and textural properties of gluten-free dough used for producing noodles based on arrowroot and finger millet powder .

2.8.3 Applications of extruders and extrusion process variables in product development

There are three major types of extruders being used in the food industry; piston extruders, roller-type extruders, and screw extruders. Screw extruders are most common extruders used these days and can be categorized as single and twin screw extruders.

2.8.3.1 Single Screw Extruder

Single-screw extrusion cooking is an attractive method for making pasta products due to its low capital cost and is a feasible process to produce nonfried instant noodles and rice noodles (Yeh and Hwang, 1995; Yeh and Tien, 1995).

In the single-screw extrusion cooking process, the extruder can be divided into three regions: conveying, swelling, and melting/degradation in terms of the transition of rice starch. Both the conveying and swelling regions are located in the cooling zone, where the flow pattern behaved as a plug flow reactor. The melting of starch granules and degradation of starch molecules occur simultaneously in the third region.

The flow pattern is changed from plug flow reactor to continuous stirred tank reactor, thus more mixing and longer residence time occurred in the heating zone. Davidson et al. (1984) and Diosady et al. (1985) postulated that only fully-cooked wheat starch (amylopectin) is susceptible to shear degradation during single-screw extrusion.

Whereas Rodis et al. (1993) suggested that both shear and thermal fields in a single-screw extruder affect the fragmentation of corn starch at temperatures higher than 100°C and moisture levels lower than 30%. Van Zuilichem et al. (1990) suggested that the length-to-diameter ratio of the barrel should be greater than 30 in order to attain reasonably higher dextrose equivalent values.

Research also indicate that significantly higher dextrose equivalent values can be obtained with a longer barrel, such as a 1222 mm (Hakulin et al., 1983). Esseghir and Sernas (1994) have measured the temperature distribution in the screw channels of a single-screw extruder using a cam-driven thermocouple synchronized with the rotating screw shaft. In another experiment, Goedeken (1991) investigated single screw extrusion cooking of corn starch with selected proteins in which dairy proteins showed good results, such as acceptable expansion, but they also indicated a 446 M. S. ALAM ET AL

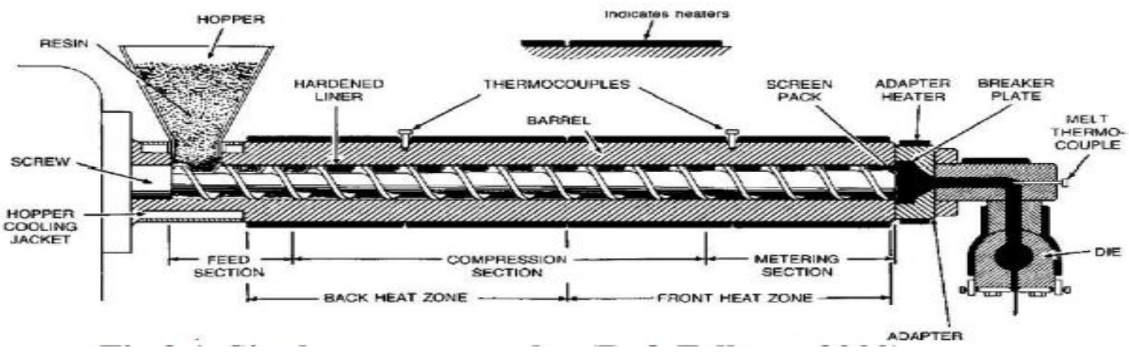

Fig 2.3 single screw extruder

Extrusion technology has gained in popularity due to following reasons (Fellows, 2000)

• Versatility - A very wide variety of products is possible by changing the ingredients, the operating conditions of the extruder, and the shape of the dies. Many extruded foods cannot be easily produced by other methods.

• Reduced costs - Extrusion has lower processing costs and higher productivity than other cooking or forming processes. Some traditional processes, including the manufacture of cornflakes and frankfurters, are more efficient and cheaper when replaced by extrusion.

• High production rates and automated production - Extruders operate continuously and have high throughputs. For example, production rates of up to 315 kg/h for snack foods, 1200 kg/h for low-density cereals, and 9000 kg/h for dry expanded pet foods are possible.

• Product quality - Extrusion cooking involves high temperatures applied for a short time and limited heat treatment, therefore, retaining many heat-sensitive components.

• No process effluents - Extrusion is a low-moisture process that does not produce process effluents. This eliminates water treatment costs and does not create problems of environmental pollution.

A study on physicochemical characteristics, nutritional quality, and shelf life of pearl millet-based extrusion cooked supplementary foods was done by Sumathi *et al.* (2007). The cold and cooked paste viscosity, the melt energy, and the carbohydrate digestibility of the extrudates indicated that the products were precooked and were of ready-to-eat nature. The millet was blended with grain legumes (30%) and with defatted soy (15%) separately and extruded to prepare ready-to-eat nutritious foods suitable as food supplements to children and mothers. The foods based on the millet and legumes and the millet and soy contained 14.7% and 16.0% protein with 2.0 and 2.1 protein efficiency ratio values, respectively. The shelf-life of the foods was about 6 months in different flexible pouches at ambient storage conditions.

Chaiyakul *et al*. (2009) studied the effect of extrusion conditions on the physical and chemical properties of high protein glutinous rice-based snacks and concluded that high protein nutritious snacks obtained from glutinous rice flour; vital wheat gluten and toasted soy grits even at increased feed moisture and reduced barrel temperature. The feed moisture and temperature providing high expansion, low bulk density, and low shear strength of extruded snack were of 20 g/100 g wb and 180°C.

Devi (2012) reported the development of pasta products using different small millets namely, little, foxtail, kodo, proso, and barnyard using wheat flour as a binder. Sensory evaluation of various products indicated that the pasta extruded from the formulation proso is to wheat flour was best in terms of its quality.

Lakshmi *et al.* (2013) developed pasta products using refined wheat flour, semolina, green gram, black gram, cheese flavour, and fish mince with a lab-scale extruder. Acceptability studies on the pasta products were conducted initially and at the end of the storage period that is, two months at the laboratory level by a panel of judges using a 5-point hedonic scale. Among the different blends studied, the most acceptable pasta was the product made with a combination of refined wheat flour + semolina + black gram dal + cheese flavour + fish.

Extrusion has an impact on the qualities of food products due to high temperatures. The major impact is on nutritional qualities along with physicochemical properties. The nature of the protein, starches, and other constituents will be changed due to alterations in chemical structure. Various types of extruders are utilized to produce extruded items. By using different types of basic and raw ingredients, the extrusion cooking technology produces several food items for human consumption for their diet with various textures, shapes, flavours, and colours. Shelar & Gaikwad (2019) studied the extrusion in the food sector along with extrusion type and impact of extrusion on different properties of food products.

Putri *et al*. (2021) did research on food diversification based on the optimal use of local foodstuff of cassava and tempe flour, and to increase public food consumption pattern of non-rice food by making analogue rice fortified with cassava flour and protein tempe flour using cold extrusion method as functional foods for vegetarians.

2.8.3.2 Twin screw extruder

It is a common practice in the art of extrusion cooking with twin-screw extruders, to employ a section of spirally flighted screw elements behind the die head zone to provide a steady pumping action and to generate high die pressure. However, Roberts and Guy (1987) found that the equilibrium operating state in such a configuration is prone to catastrophe (i.e. sudden change) and metastability.

Wang et al. (2012) developed pea starch noodles using twin-screw extruder and observed that increasing dough moisture content increased the b value (yellowness), expansion ratio, percentage of gelatinized starch, resistant starch content, cooking time, firmness and surface stickiness, but reduced cooking loss. Bakalis and Karwe, 1999 investigated two velocity components, namely the transverse (Ux), and the axial (Uy) and measured these velocities in the nip region of a 14 mm pitch screw element at screw speeds of 90, 60, and 30 rpm. The velocity distributions were very different from those reported in the translation region, indicating the distinct character of the nip region. While Ux did not vary significantly with respect to the angular position, the axial velocity component, Uy, varied significantly. The screw speed did not affect the shape of the velocity distributions; it only affected the velocity values. In another study, Pilli et al. (2005) investigated the effects of some operating conditions on oil loss and physical properties of products obtained by doughs containing almond flour extruded in a co-rotating twin-screw extruder. The lowest loss of oil was obtained at low percentages of dough moisture and high values of screw speeds and the best results were obtained by extruding at 36% dough moisture and 200 rpm screw speed.

The operating conditions suitable to obtain both a low oil loss and a good product structure were low percentages of dough moisture and high values of screw speed and extrusion temperature. The effects of eggshell powder on the extrusion behavior and extrudate properties of rice in a corotating twin-screw extruder was investigated by Chung (2007). Microstructure of eggshell powder-added extrudates showed a fine and friable texture with thinner cell walls and more cell numbers. With increase in levels of eggshell powder could increase L* values but decrease b* values of extrudates. Stojceska et al. (2009) used co-rotating twin-screw extruder for wheat flour and corn starch with the addition of 10% brewer's spent grain and red cabbage.

Choudhury and Gautam (2003) studied the effects of hydrolyzed fish muscle on intermediate process variables during twin-screw extrusion of rice flour. Hydrolysis of arrow tooth muscle beyond 5 minute had very little effect on energy input, residence time, mixing index, and die temperature. Fish solids level played a dominant role in lowering specific mechanical energy input, raising the mean residence time, and reducing mixing.

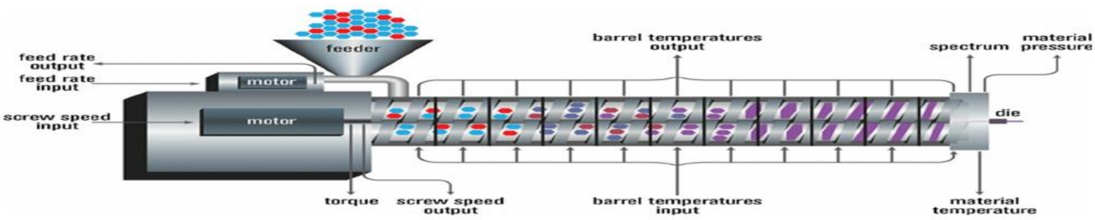

Fig 2.4 Twin screw extruder

2.9 RAW MATERIALS

2.9.1 Arrowroot powder

Arrowroot powder is a starchy substance extracted from the rhizomes, or underground stems , of the arrowroot plant (Maranta arundinacea).

Here are some details about arrowroot powder:

- Starch Content: Arrowroot powder is primarily composed of starch, making it a popular thickening agent in cooking and baking. It contains a higher concentration of starch compared to other thickeners like cornstarch.
- Gluten-Free: Arrowroot powder is gluten-free, making it a suitable alternative for those with gluten sensitivities or celiac disease. It's often used in gluten-free recipes as a thickening agent.
- Neutral Flavor and Clear Appearance: One of its advantages is its neutral taste, which doesn't interfere with the flavors of the dishes. It also imparts a clear, glossy finish to sauces and fillings, making it preferred in certain culinary applications.
- Thickening Agent: Arrowroot powder is commonly used to thicken sauces, soups, and gravies. To use it as a thickener, mix it with a small amount of cold liquid to form a slurry before adding it to the hot mixture. Unlike cornstarch, arrowroot doesn't break down when subjected to acidic ingredients.
- Heat Sensitive: Arrowroot thickens at a lower temperature than cornstarch, so it's ideal for delicate sauces that shouldn't be boiled for an extended period.
- Glazing Agent: It can be used as a glazing agent for fruit tarts and pies, giving a shiny appearance to the finished product.
- Digestive Benefits: Some traditional medicine systems suggest that arrowroot may have digestive benefits and could be soothing for the digestive tract. However, more research is needed to confirm these claims.

2.9.1.1 Nutritional facts of arrowroot powder

Table 2.1 Nutritional Facts Of Arrowroot Powder

Calories	65kcal
Total fat	0.2g
Sodium	0.26g

Protein	4.42g
Total carbohydrates	13.39g
Dietary fibre	1.3g
Calcium	0.6%
Vitamin c	3%

2.9.2 Finger millet

Finger millet powder, also known as ragi flour, is derived from finger millet grains. It is a gluten-free and nutritious alternative to wheat flour. Rich in calcium, iron, and fiber, it's commonly used in various cuisines. The powder can be used to make porridge, baked goods, or as a thickening agent in soups and stews. It's particularly popular in South Indian dishes and is valued for its health benefits, including aiding digestion and providing sustained energy due to its complex carbohydrates.

Finger millet powder, often referred to as ragi flour, is produced by milling finger millet grains. Finger millet, scientifically known as Eleusine coracana, is an annual cereal crop widely cultivated in Africa and Asia. The grains are tiny and reddish-brown, with a high nutritional value

Nutritional Composition

- Proteins: Finger millet is rich in essential amino acids, making it a good source of protein.
- Minerals: It is high in calcium, iron, phosphorus, and potassium.
- Vitamins: Contains B-vitamins, especially B1 (thiamine) and B2 (riboflavin).
- Fiber: Provides dietary fiber, aiding digestion and promoting a feeling of fullness.

Health Benefits:

- Bone Health: The significant calcium content contributes to bone strength.
- Anemia Prevention: High iron levels make it beneficial for individuals with iron-deficiency anemia.
- Digestive Health: The fiber content supports digestive health and helps prevent constipation.
- Diabetes Management: Ragi has a low glycemic index, aiding in blood sugar control.

- Gluten-Free: Ideal for those with gluten sensitivities or celiac disease.

Culinary Uses:

- Porridge: Ragi porridge is a common and nutritious breakfast option.
- Baked Goods: Ragi flour can be used in various baking recipes like bread, cookies, and pancakes.
- Traditional Dishes: It's a key ingredient in South Indian dishes like dosa and idli.

Processing:

- Harvesting: Finger millet grains are harvested when fully ripe.
- Cleaning: Grains are cleaned to remove impurities.
- Milling: The cleaned grains undergo milling to produce fine finger millet powder.
- Storage and Shelf Life: Store in a cool, dry place to prevent spoilage.The shelf life is typically several months, but it may vary based on storage conditions.

2.9.3 Nutritional facts of finger millet powder

Table 1.2 Nutritional facts of finger millet powder

Energy	328kcal
Protein	7.3g
Fat	1.3g
Carbohydrate	72g
Fiber	11.85g
Calcium	344mg
Iron	3.9g
Phosphorus	0.19g

2.10 PHYSICAL PROPERTIES

2.10.1 Colour characteristics

Iweet al. (2000) studied the effect of extrusion cooking of soy-sweet potato mixtures on the browning index of extrudates and showed the effect of processing variables such as feed composition, screw speed, and die diameter. Response surfaces for the parameters were generated using a second-degree polynomial. An increase in feed composition and screw speed increases browning index but decreases die diameter and feed composition increases browning index. Cemalettin and Mustafa (2010) performed modelling the effects of processing factors on the changes in colour parameters of cooked meatballs for studying the simultaneous effects of processing variables such as fat (10-30%), wheat bran (5- 15%), and NaCl (0-2%) on the colour changes (L*, a*, b*, whiteness index, saturation index, hue-angle, total colour difference, and browning index) of cooked beef meatballs. The results showed that the processing variables had a significant effect on the colour parameters. L* and whiteness index values of meatballs were decreased by the wheat bran addition. The 'b*' and saturation index values were increased by fat addition. An increase in the fat content increases the browning index values and salt addition showed an inverse effect. Bouasla et al. (2016) developed gluten-free precooked rice pasta enriched with legume flours and analyzed physical properties, texture, sensory attributes, and microstructure. Pasta colour is an important parameter for pasta quality assessment. Dry pasta containing yellow pea flour and lentil flour was much darker than dry rice pasta and dry pasta enriched with chickpea flour. The lightness of dry pasta samples decreased as the amount of legume flours in the 25 recipe increased. In general, dry pasta containing legume flours had a significantly more yellow colour than dry rice pasta.

2.10.2 Elongation

Peri et al. (1983) reported that the expanded volume of cereal is due to the starch content. Zhu & Khan, (2002) studied the relationship between amylase content and extrusion-elongation properties of corn starches. Corn starch with upto 70% amylose contents was extrusion cooked at different temperatures of 130 to 160°C and moisture contents of 0 to 50% (db). The product quality measures of elongation, shear strength and bulk density were studied about the starch amylase content. Zhu & Khan (2002) reported that gluten has viscoelastic behaviour in which gliadin and glutenin fractions represent viscous and elastic behaviour, respectively. Variation in protein content alone is not responsible for the differences in dough properties and suitability for end-products amongst the cultivars. Bouasla et al. (2016) reported that the expansion ratio was significantly higher for rice precooked pasta compared to pasta samples enriched with legume flours. The expansion process is affected by starch gelatinization and starch breakdown. An increase in protein and fibre content would increase the viscosity of dough inside the extruder resulting in longer residence time and a higher shearing rate, which may cause a molecular degradation of the amylopectin molecule, which led to a decrease in expansion ratio. Cimini et al. (2020) studied the effect of cooking temperature and cooked pasta quality and sustainability. They found out that the lower the cooking temperature, the lesser the degree to which the cooked sample returned to its original shape. Such a loss of elasticity might be attributed to the fact that the mechanical resistance of the gluten network, as well as its elastic modulus and elongation, decreased as the temperature was reduced from 135-80°C.

2.10.3 Water activity

Ribeiro et al. (2021) studied the storage stability of durum wheat pasta enriched with seaweed flours. Water activity was shown to be the main criteria influencing the quality parameters of pasta during shelf life. In this work, the water activity of all samples after 6 months of storage was measured at 20°C for each condition of temperature and relative humidity studied, and the different kinds of pasta presented a similar water activity. It was found that dried pasta of any composition has stability that prevents damage due to low water activities. Vieira et al. (2021) studied the effects of long-term frozen storage on the quality and acceptance of gluten-free cassava pasta. Water activity is a physical parameter because it directly influences the product's shelf life. Two different formulations comprised of 100% cassava starch and 100% wheat flour were developed. Water activity presented no significant difference between both samples. Water activity for both formulations showed values superior to 0.9, demonstrating its susceptibility to microbial growth, thus requiring proper techniques for its processing.

2.11 COOKING CHARACTERISTICS

2.11.1 Optimum cooking time

Kaur et al. (2010) studied the functional properties of pasta enriched with variable cereal brans. It was found that optimum cooking time was less for pasta that contained cereal bran as compared to durum wheat semolina pasta. The optimum cooking time was 5:38 min. for control pasta, which was reduced to 5:24 min., 5:22 min.,5:17 min., and 5:22 min. for wheat, rice, barley, and oat bran enriched pasta at a 25% level of supplementation. This may be due to the physical disruption of the gluten matrix by the bran and germ particles which provided a path of water absorption into the whole wheat spaghetti strand that also reduced cooking time.

Pastificio et al. (2011) concluded in a study in which durum wheat was milled to obtain medium (M), medium-coarse (MC), and coarse (C) semolina with an average particle size of 275, 375, and 475 μm respectively. The three semolina were characterized for their chemical and physical properties. The M semolina showedhigher gluten extensibility, higherash, protein, and gluten content, but a lower gluten index and yellow colour than coarser semolina. Spaghetti was produced with three semolina. Dried spaghetti was characterized byits diameter, hardness, and colour and was eventually tested for its cooking quality. Spaghetti from MC and C semolina showed higher optimum cooking time (OCT) than spaghetti from M semolina. Cooking time being equal, the weight and diameter increase was higher in spaghetti from coarser semolina. Within OCT, the hardness of spaghetti from MC and C semolina was higher than that of spaghetti from M semolina. The high OCT and hardness (before OCT) of the semi-cooked pasta obtained from MC and C semolina could be useful in two-step cooking processes in which pasta is pre-cooked and cooled before the final cooking step. Cimini et al. (2020) studied the effect of cooking temperature on cooked pasta quality and sustainability. The primary purpose of this work was to determine the effect of cooking temperature on the optimum cooking time (OCT). It was concluded that as the cooking temperature was reduced the optimum cooking time exhibited an exponential increase.

2.11.2 Solid loss

Bhaskaran et al. (2011) conducted a study in which statistical analysis revealed a highly significant difference in the total solid loss between the control and the noodles enriched with SMP, as well as the combination of SMP and WPC. The total solid loss in gruel increased as the level of substitution increased (Khan et al., 2013). The increase in loss due to enrichment may be related to gluten dilution and the protein solubility fraction of wheat germ. The results conformed with Olfat et al. (1993) and Fayed et al. (1993). The total solids loss was higher in the noodles substituted with SMP when compared to WPC. This may be attributed to the compact structure of WPC and the porous nature of the SMP enriched noodles. Total solids loss in gruel increases as the level of substitution increases.

It was also found that the loss of total solids was higher in noodles supplemented with skim milk powder compared to whey protein concentrate and a combination of SMP and WPC. Similar effects on cooking losses have been reported for pasta products incorporating non-durum ingredients such as seaweed (Prabhasankar et al., 2009), dietary fibre (Tudorica et al., 2002), banana flour (Ovando et al., 2009). Sereewat et al. (2014) studied the cooking properties of spaghetti made from rice flour and defatted soy flour. The addition of modified starch increased of cooking time, cooking weight, and tensile strength of rice spaghetti after cooking. Cooking loss ranged from 6.74- 8.19 g/100 g of dry noodles.

2.11.3 Swelling power

Swelling power is a measure of hydration capacity because the determination is a weight measure of swollen starch granules and their occluded water (Rickard et al., 1992). Food-eating quality is often connected with the retention of water in the swollen starch granules (Abraham and Jayamuthunagai., 2014). The low swelling power of starches might be attributed to the presence of many crystallites formed by the association between long amylopectin chains. Crystallite formation increases granular stability, thereby reducing the extent of granular swelling (Miao et al., 2009). The swelling volume of starch was affected by amylose content and the structure of amylopectin (Sasaki and Matsuki, 1998). Surasaniet al. (2019) studied the functionality and cooking characteristics of pasta supplemented with protein isolated from pangas processing waste. The incorporation of pangas processing isolate content in pasta caused a significant increase in water absorption capacity, water solubility index, and pasting temperature but decreased oil absorption capacity and viscosity. No significant difference in the water uptake ratio and swelling power were observed with the addition of pangas processing isolate.

2.12 NUTRITIONAL CHARACTERISTICS

2.12.1 Proximate analysis

Kaur et al. (2010) conducted experiments on the functional properties of pasta enriched with variable cereal brans. Results of proximate analysis of the raw material used in the production of dietic pasta, durum wheat semolina had 11.7% protein whereas the protein content of cereal bran ranged from 9.6-15.0 %. Rice and barley brans had protein values at par. The fat content ranged from 1.81 to 19.3% and was highest for rice bran. Dietary fibre was highest for rice bran (38.9%). Barley bran had the maximum value for crude fibre (14.9%). Maximum ash content (6.72%) was observed in rice bran samples. Bouaslaet al. (2016) presented that protein, ash, and fibre contents increased with the incorporation of legumes flours. Reduction of lipids extractability is observed due to formations of amylose lipids complexes during pasta making by extrusion cooking. The protein content and protein nutritional value of pasta products were improved by the addition of legumes flour due to the complementation of cereals and legumes amino acids. Nochera&Ragona (2019) developed a pasta product using breadfruit flour, tested the sensory qualities of breadfruit pasta products by sensory evaluation, and evaluated the nutritional composition. Nutritional labelling shows that the breadfruit pasta product is high in carbohydrates and low in fats. Bolarinwa&Oyesiji (2021) determined soy-enriched rice pasta's quality attributes. The proximate composition showed increase in protein (6.7-12.1%), crude fibre (0.8-1.3%), ash content (0.6-2.2%) and energy values (379- 389kcal/100 g). This study demonstrated that rice soy pasta can serve as a nutritious alternative to the conventional rice pasta and add variety to food groups for people suffering from celiac disease.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the methodologies used for the development of gluten free noodles from Arrowroot powder and Finger millet powder (Ragi flour) by extrusion process. The quality parameters of the developed pasta product and its storage studies are also explained in this chapter.

3.1 RAW MATERIALS

Raw materials selected for the study were arrowroot powder and finger millet.

3.2 PREPARATION OF SAMPLE

Good quality arrowroot, finger millet were procured from the market at Tavanur. These materials were then subjected to preliminary treatments.

3.1.2 Finger millet Flour

Finger millets obtained were soaked for 16 hours and allowed to germinate (48 hours). The germinated finger millet was then dried in a cabinet dryer at 60°Cuntil the required moisture content was attained. Vegetative parts were removed by rubbing and the millets were ground to powder using a pulverizer. 33 Carrot flour and finger millet flour were then blended with chickpea flour, corn flour, rice flour and guar gum in different proportions.

3.1.3 Arrowroot powder

Arrowroot flour is normally made by grinding or blending a high carb plant, adding water, mixing, pouring the water in to the vessel to settle, pouring the water off leaving a paste in the bottom of the vessel & tending the paste to dry in the sun.

3.3 EXTRUSION PROCESS

A single screw extruder La Monferrina Dolly 10D044 (Plate 3.1) was selected for the preparation of noodles. The screw zone of the extruder is divided into five sections – feed section, cooking section, blending section, extruding section and cutting section. Feed section allows the flour to get uniformly mixed inside the extruder. The cooking section consists of a flat plate through which the ingredients get heated up to the required temperature. Blending section consists of a rotating screw with pressure variance in which the particles of the blend are brought together. Extruding section contains an extruder die with the required size to enable puffing of the product. At cutting section, the expelled extrudates are sliced to a specific length as per our requirements.

Fig 3.1 Single Screw Extruder

FLOW CHART FOR PRODUCTION OF GLUTEN FREE NOODLES

Raw materials (In different combinations as defined)

↓

Kneading (10 min)

↓

Conditioning with water (25, 30, 35 % moisture content, wb)

↓

Extrusion

↓

Drying (60° C,3hrs.)

↓

Gluten free noodles

Flow chart of production of gluten free noodles

3.4 OPTIMIZATION OF PROCESS PARAMETERS

3.4.1 Feed composition

Nutritious food is needed to sustain life and activity. Our diet must provide all essential nutrients in the required amounts. Carbohydrates, fats, and proteins are macronutrients needed in large amounts. Vitamins and minerals constitute the micronutrients required in small amounts. Carbohydrates are the major source of 35 energy in all human diets. Proteins are the primary structural and functional components of a living cell. Vitamins are chemical compounds required by the body in small amounts. As all the vitamins cannot be synthesized by the human body, they are to be supplied through the diet. Based on this, the feed composition of gluten free noodles was prepared with arrowroot powder and finger millet in equal proportion it is a gluten free and nutritious alternative to wheat flour and they are a rich source of calcium, fibre, and iron. Arrowroot powder was selected due to gluten free making it a suitable alternative for those with gluten sensitiveness or celiac disease its often used in gluten free recepies as a thickening agent.

3.4.2 Kneading time

Kneading is the process of working a dough mixture to form a smooth and cohesive mass. Kneading time influence the properties and growth of dough. Based on our product we finally optimise 10 min kneading time were selected in this study which determine our product quality.

3.4.3 Moisture content

Moisture content is simply how much water is in a product. It influences the physical properties of a substance .knowing and controlling the moisture content in food is vital to ensure consistently high standard of products.

Fig 3.2 Infrared Moisture Meter

3.5 QUALITY EVALUATION

3.5.1 Physical Properties

3.5.1.1 Colour

Product colour is a strong indicator of the thermal history within the extruder. Hunter lab colorimeter is used for the measurement of colour. It works on the principle of focusing the light and measuring the energy reflected from the sample across the entire visible spectrum. This system uses three values viz. ‘L*’, ‘a*’, and ‘b*’ to describe the precise location of colour inside a three dimensional visible colour space. The colorimeter was calibrated against standard white and black tiles before each actual colour measurement. For each sample, at least four replications were performed at different positions and the mean values were taken. Measurements displayed in L*, a*, and b* values represents light-dark spectrum with a range from 0 (black) to 100 (white), the green-red spectrum with a range 38 from - 60 (green) to + 60 (red) and the blue - yellow spectrum with a range from - 60 (blue) to + 60 (yellow) dimensions respectively (Ali et al., 2008).

Fig 3.3 LoviBond Colorimeter

3.5.1.2 Water activity

Water activity is the ratio of the vapour pressure of water in a material or substance to the vapour pressure of pure water. The water activity of the pasta samples was measured using a water activity meter. A water activity test works by placing a sample in a sealed measuring container.

Fig 3.4 Water activity meter

3.5.1.3 Elongation

The percentage elongation of cooked and uncooked pasta was analyzed by using a digital vernier calliper. The percentage elongation wascalculated by using the formula: Percentage Elongation = (Initial – Final) × 100 /Initial (1)

Fig 3.5 digital vernier calliper

3.5.2 Cooking characteristics

3.5.2.1 Optimum cooking time

Optimum cooking time is measured using the manual method by pressing the product between fingers periodically at 1-minute intervals. When the product was completely soft, the time was noted .

3.5.2.2 Swelling power

A known weight of 5 g of pasta was cooked in a glass beaker with 100 ml water for 20 min r a water bath maintained at 100°C. After cooking, the water was drained out. The cooked pasta was dried using filter paper to remove the excess moisture. The cooked sample was weighed. The swelling power was calculated using the equation given below:

$$\text{Swelling power} = \frac{(\text{Sample weight after cooking} - \text{Sample weight before cooking})}{\text{Sample weight before cooking}} \ldots(2)$$

3.5.2.3 Solid loss

It was determined by cooking pasta in boiling water for 20 minutes. After cooking, the cooked materials were retained. The whole filtrate was transferred quantitatively into a pre-weighed Petri dish. It was evaporated over a water bath followed by drying for 1 hour at 60°C. The Petri dish was again weighed with dried solids

Solid loss percentage = $(M_2 - M_1) \times 100/M_0$…………..(3)

M_0 = Weight of pasta taken for cooking

M_1 = Weight of empty Petri dish

M_2 = Weight of Petri dish with dried solids evaporation

3.6 NUTRITIONAL ANALYSIS OF THE OPTIMIZED MIX

Proximate analysis: Nutritional analysis viz. carbohydrate, protein, fat, ash, and moisture content were conducted for the optimized sample using standard procedures

3.6.1 Moisture content

The moisture content of the sample was determined using an infrared moisture meter.

3.6.2 Carbohydrates

Estimation of total carbohydrates is done by the anthrone method. Carbohydrates are first hydrolyzed into simple sugars using dilute HCl. In a hot acidic medium, glucose is dehydrated into hydroxymethylfurfural. This compound reacts and forms a green-coloured product with an absorption maximum of 630 nm.

Amount of carbohydrate in 100 mg of sample $= \frac{mg\ of\ glucose * 100}{The\ volume\ of\ test\ sample}$

3.6.3. Protein

Protein can be estimated by different methods as described by Lowry and also by estimating the total nitrogen content. No method is 100% sensitive. Hydrolysing the protein and estimating the amino acids alone will give the exact quantification. The method developed by Lowry et al. is sensitive enough to give a moderately constant value and hence largely followed. Protein content of enzyme extracts is usually determined by this method.

The blue colour developed by the reduction of the phosphomolybdic-phosphotungstic components in the Folin-Ciocalteau reagent by the amino acids tyrosine and tryptophan present in the protein plus the colour developed by the biuret reaction of the protein with the alkaline cupric tartrate are measured in the Lowry's method.

3.6.4 Ash content

A high-temperature muffle furnace capable of maintaining a temperature between 500-600°C is used for determining ash content. Water and other volatile materials are vaporized and organic substances are burned in the presence of oxygen in the air to CO_2, H_2O, and N_2. The weight of the crucible with the sample is noted before and after burning. The percentage of ash is calculated using the equation:

$$\text{Percentage of ash} = (W2 - W1) / W3 \times 100$$

W1 = Weight of crucible

W2 = Weight of crucible with ash

W3 = Weight of sample

3.6.5 Crude Fiber

Crude fiber content was determined as per the method described by (Maynard, 1970). The dried sample was taken in the pre weighed glass crucible (W1) it was placed in crucible holder with the glass extractor. 150 ml of pre heated 1.25% H_2SO_4 was added in the extractor and the contents are boiled for 30 mins at 500◦C and 30 mins for 400◦C. The acid residue was drained out from the extractor through fibra flow system. The residue was washed with distilled water. Then 150 ml of pre heated 1.25% NaOH added and digested for 30 mins at 500◦C and 30 mins at 400◦C. Then the residue was washed with distilled water and dried for two to four hours at 100◦C, cooled and weighted.

$$\text{Crude fiber (\%)} = \frac{(W3 - W2)}{W1} \times 100$$

W1= Weight of sample used

W2 = Weight of crucible

W3 = Weight of residue with crucible

CHAPTER IV
RESULT AND DISCUSSION

This chapter deals with the results and discussions of the experiments conducted for the development of gluten free noodles from arrowroot powder and finger millet. The storage studies of the optimally produced noodles product were also studied and discussed in this chapter.

4.1 PHYSICAL PROPERTIES

4.1.1 Colour

Colour is one of the important property of food product which is related to consumer acceptability.

Lovibond colorimeter values of the cooked and uncooked sample

Table 4.1 Lovibond Colorimeter Readings

Treatment	Uncooked					Cooked				
	L*	a*	b*	c*	h*	L*	a*	b*	c*	h*
Control	72.29	-4	29.25	35.37	12.72	79.07	-5.25	30.71	38.51	11.77
Sample	19.63	9.5	8	12.43	39.96	16.34	7.38	6.41	22.34	32.78

4.1.2 Elongation

The percentage elongation is higher for the control sample and Moreover, Noodles dough enriched with arrowroot and finger millet powder tends to be more viscous than those with wheat flour (control sample), the pressure differential between the value generated by the die and the atmospheric pressure would be smaller for enriched noodles, causing a reduction of expansion ratio (Singh et al. 2007).

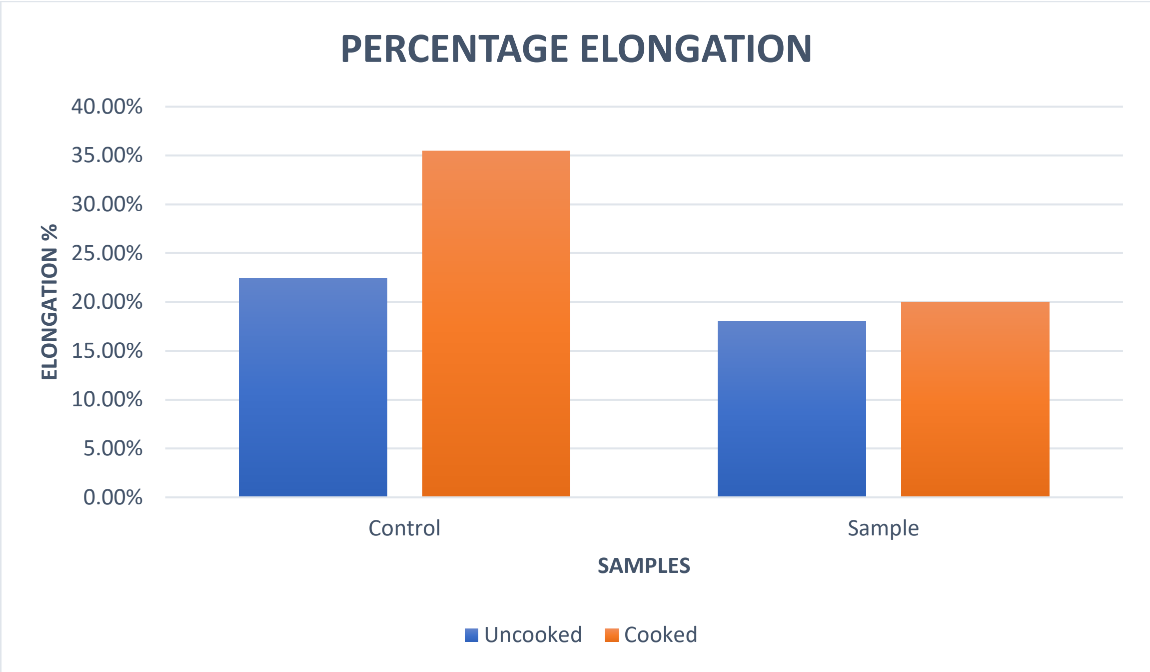

Fig. 4.1 Elongation Of Gluten Free Noodles

4.1.3 Water Activity

The table represents the water activity of different control sample and arrowroot, noodles sample. The water activity of sample was found to be .582 which is higher than that of the control sample.

Water activity of uncooked noodles:

Table 2.2 Water activity of uncooked noodles

Sample	Water activity
Control	0.321
Product	0.582

4.2 COOKING QUALITIES

4.2.1 Optimum Cooking Time OCT

Figure reports the pasta cooking time evaluated in this study. Cooking quality parameters (OCT, swelling power and solid loss) were evaluated. It is observed that the OCT is required for the control (11 min) and for samples (6 min). Compared to wheat-based noodles arrowroot and finger millet based noodles have lower cooking time due to pre-gelatinization of arowroot flour and higher water absorption index (Raina, 2005).

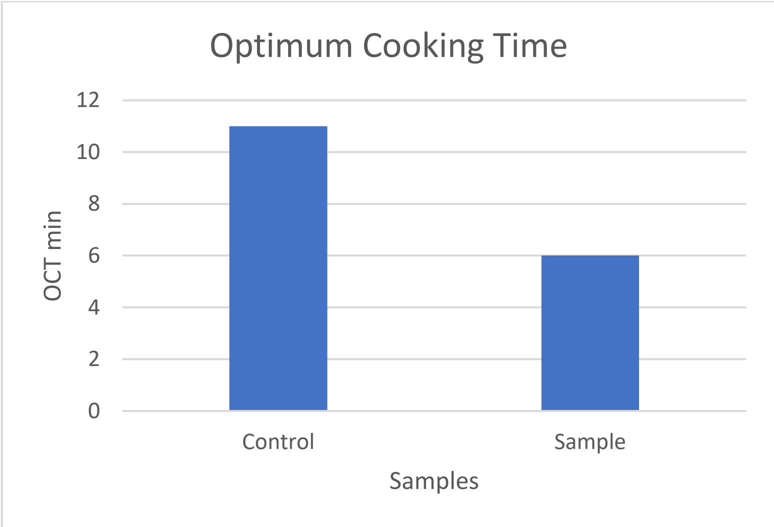

Fig. 4.2 Optimum Cooking Time of control and sample

4.2.2 Swelling power

Water absorption capacity is defined as the ratio of the weight of water absorbed by the material in the saturated state over the weight of the dry material. Food eating quality is often connected with the retention of water in the swollen starch granules. (Rickard et al., 1992). The swelling power of noodles enriched with 50 % arrowroot flour and finger millet powder 50 % is less than that of the control sample.

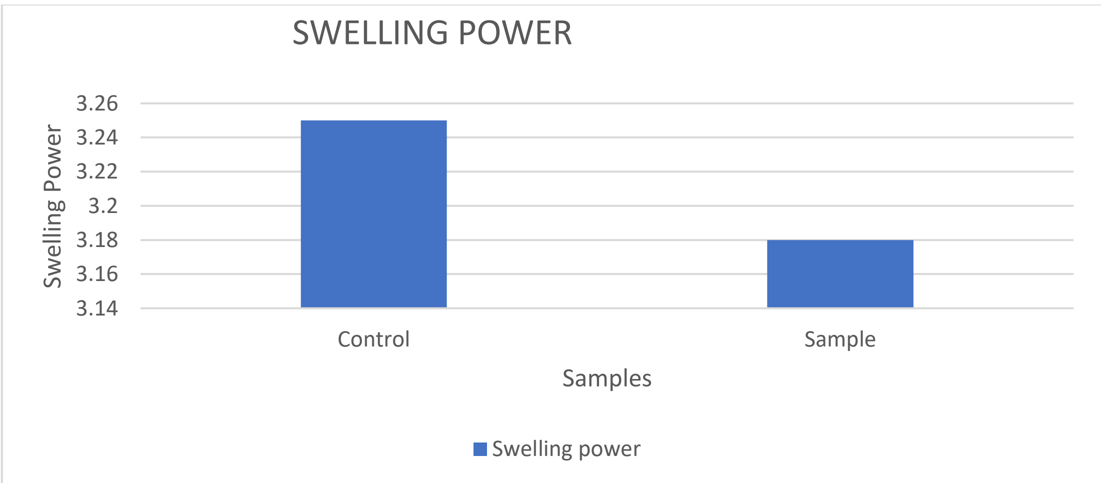

Fig. 4.3 Swelling power

4.2.3 Solid loss

Cooking loss is a measure of the amount of solid lost into the cooking water, which is considered an important factor. The total solid loss of control pasta was found to be 3.02% after 11 min of cooking. Solid loss of the sample was 7.25%. The increase in cooking loss observed can be attributed due to the absence of gluten protein in the flours (Bhaskaran et al., 2011). Also, since the gluten protein network is responsible for retaining noodles's physical integrity during cooking, a weaker structure leaches more solids from pasta samples into the cooking water increasing cooking residues (Khan et al., 2013). Cooking loss significantly increases with increase in the amount of arrowroot and finger millet powder. This increase in cooking loss is due to the weakness of the starch network by the presence of fibre as reported for gluten-based materials and gluten-free materials (Cabrera-Chavez et al., 2012). However, obtained range of cooking loss is lower than 10 % reported as the quality limit for noodles, indicating good quality of all pasta samples (Kim et al., 1996; Wang et al., 1996;)

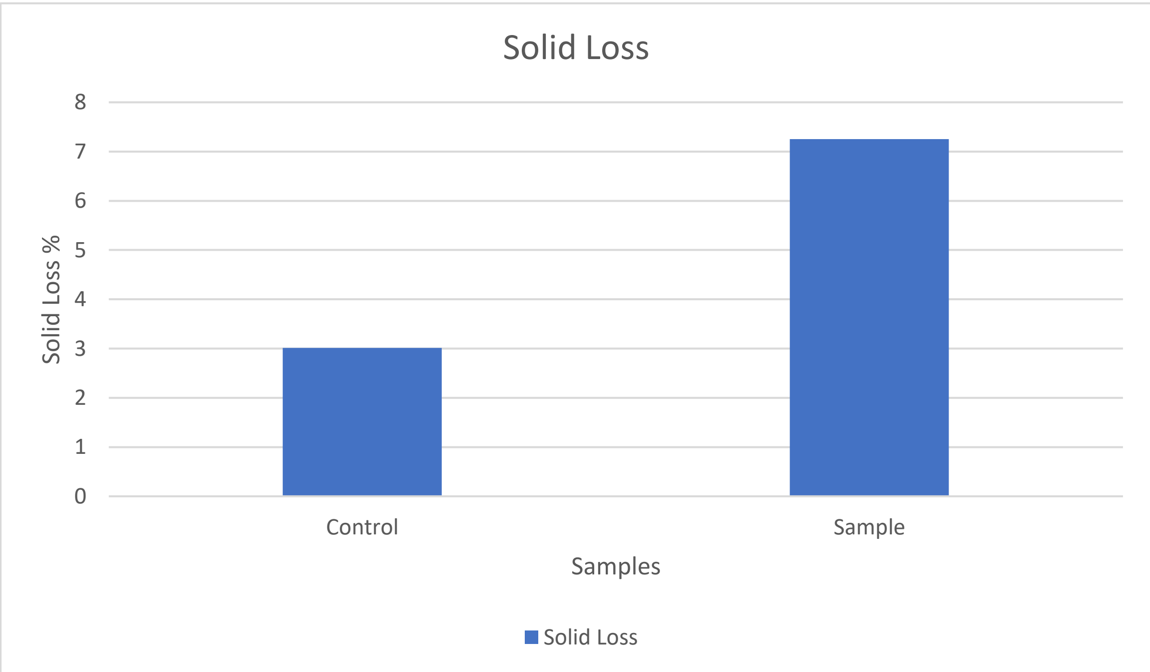

Fig. 4.4 Solid Loss During Cooking

4.3 NUTRITIONAL CHARACTERISTICS

4.3.1 Moisture Content

Moisture content in food is an inevitable factor which decides the quality, shelf-life other parameters (Smith et al., 2018; Patel and Jones, 2020). Moisture content of the control sample was found to be 2.21% whereas the moisture content of the product was 2.829% which shows that the food material is shelf stable.

Moisture Content of the Control sample : 2.21%

Moisture Content of the Gluten free noodles: 2.829%

4.3.2 Carbohydrates

Noodles, a staple in many diets globally, exhibit diverse carbohydrate compositions. A comprehensive study by Chen et al. (2019) revealed variations in carbohydrate content among noodle varieties, with ranges spanning from 40% to 75%. These disparities are attributed to differences in raw ingredients, processing methods, and regional culinary practices (Tanaka & Lee, 2020). Moreover, research by Gupta et al. (2018) emphasized the significance of accurate carbohydrate analysis in noodles due to its direct impact on nutritional labelling and dietary recommendations.

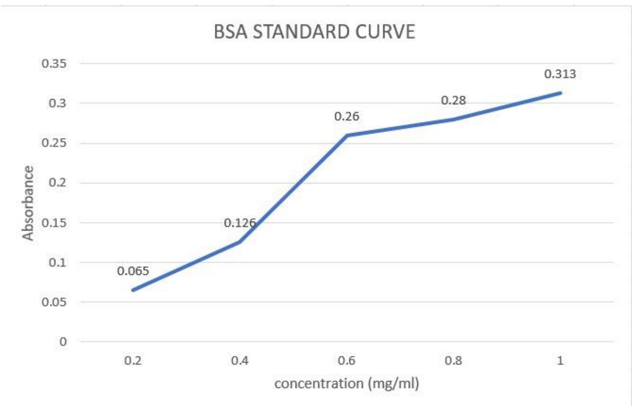

Fig. 4.5 BSA standard curve of carbohydrate

Carbohydrate content of control sample was found to be: 70 %

Carbohydrate content of gluten free noodles was found to be : 73.4%

4.3.3 Ash Content

Ash content, a key indicator of mineral content in food, was investigated in various noodle samples. Results indicated variations in ash levels, with a range of 0.5% to 1.2%. This aligns with findings in a study by Chen et al. (2019), highlighting the impact of raw material quality and processing methods on ash content. The study emphasizes the importance of controlling ash levels for nutritional quality and consumer satisfaction (Li and Wang, 2021). The ash content of the control sample was found to be 2% and for the gluten free noodles it was 5%.

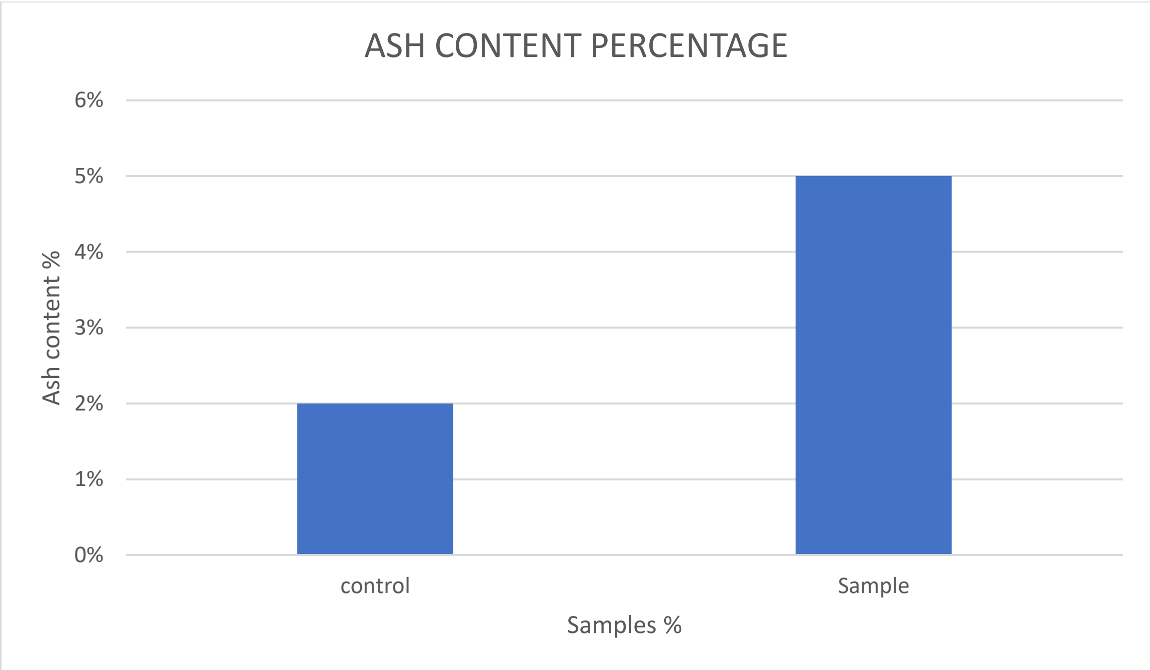

Fig. 4.6 Ash content

4.3.4 Protein

Protein content in noodles varies significantly based on ingredients and processing methods. A study by Wang et al. (2019) found that incorporating legume flours increased protein levels, enhancing nutritional value. Conversely, extrusion cooking negatively impacted protein content in wheat-based noodles (Li et al., 2020). These findings underscore the importance of ingredient selection and processing techniques in optimizing protein content, crucial for consumer health and product quality. Protein content of the gluten free noodles is less than that of the control sample.

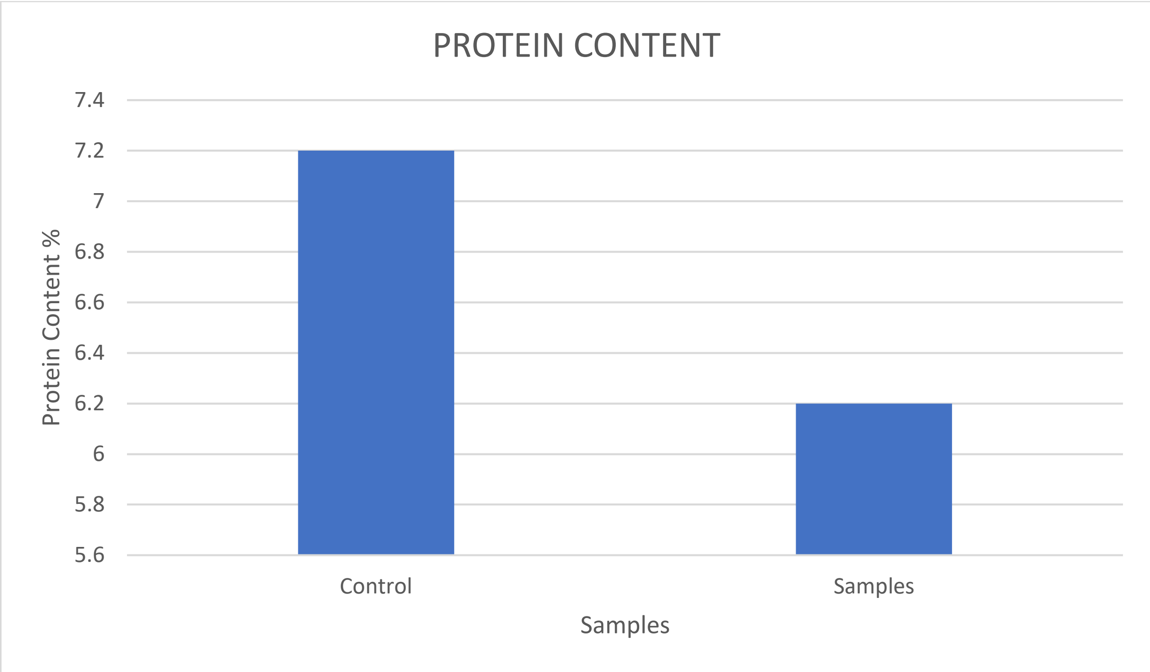

Fig. 4.7 Protein Concentration

4.3.5 Crude Fiber

The investigation revealed varying fiber levels (2.5% to 5.8%) influenced by raw material differences and processing methods (Chen et al., 2019; Gupta and Singh, 2021). The study underscores the need for standardized labeling and nutritional information in the noodle industry. Accurate fiber determination is crucial for consumers seeking dietary fiber intake.

It was found that the gluten free noodles has an higher fiber content which is of 4/100g and for control sample the value of fibre content is 1.4/100g.

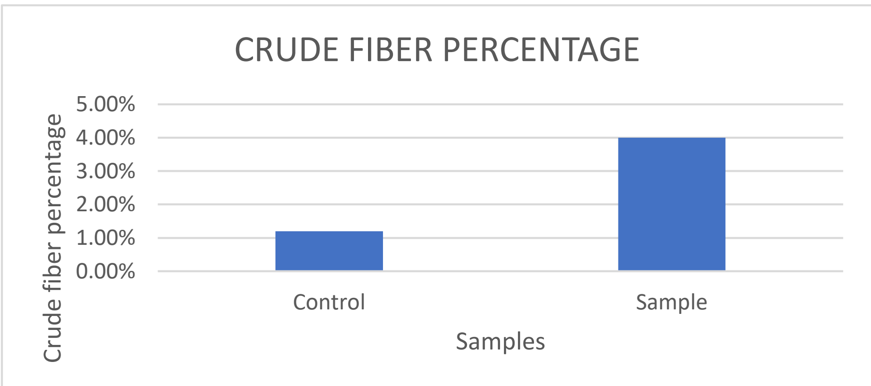

Fig. 4.8 Crude Fiber

4.4 OVERALL ACCEPTABLITY

The success or failure of a newly expanded food product is directly related to sensory attributes, where texture plays a major role (Iwe, 2000; Anton *et al*., 2007). The sensory analysis represents the unique tool for the determination of organoleptic properties of food using human senses because it is highly correlated with the consumers' attitude (Jing et al., 1991). At the same time, the prepared samples of pasta were cooked and kept for sensory evaluation. The scores given for different treatments on different organoleptic traits namely, colour, taste, texture, and overall acceptability were represented in Fig. 3.2.

Sensory evaluation was carried out by a panel of 4 judges from the students of KCAET college by giving them a scorecard. Noodles samples were presented in a random order to each judge. The judges were asked to score different quality characteristics. The scores given for different treatments on different organoleptic traits namely, colour, taste, texture, and overall acceptability. Texture of sample was chosen as the best..

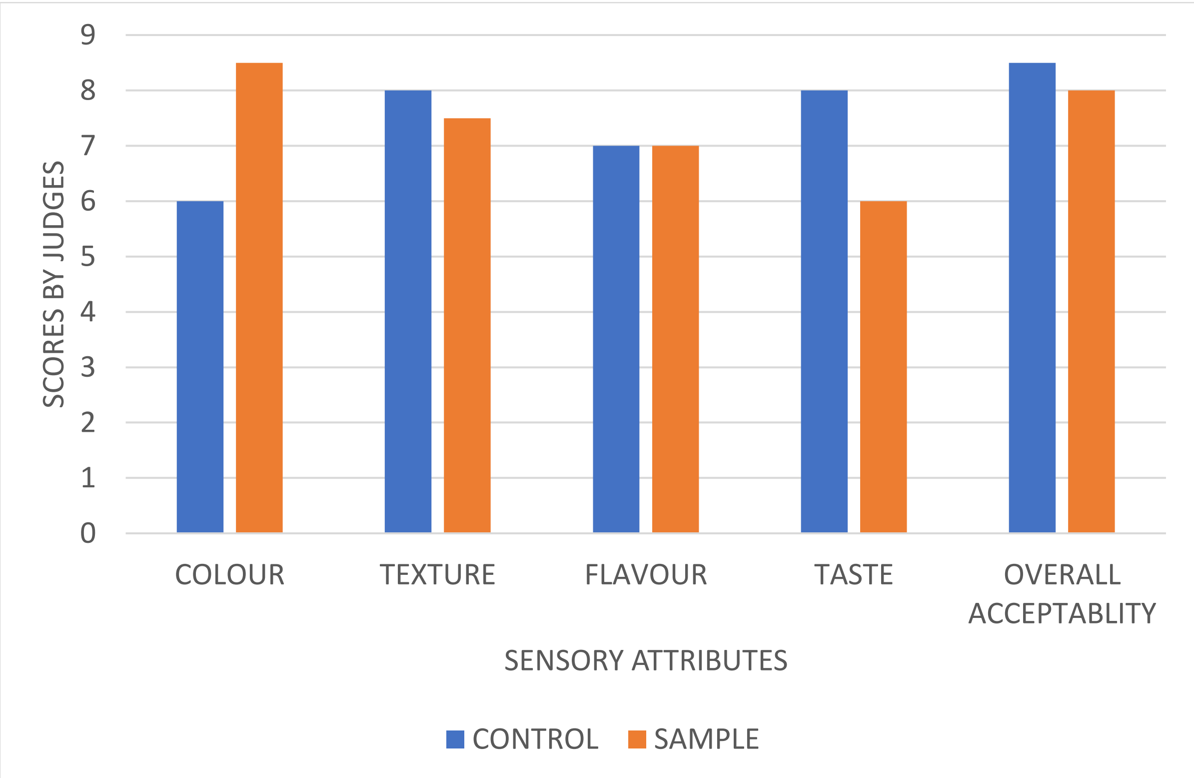

Fig. 4.9 Sensory Evaluation

Plate 4.1 Gluten Free Noodles

CHAPTER V

SUMMARY AND CONCLUSION

Food is consumed in combinations. The synergy between foods with other is vital not only for the taste and delight of eating but also for their high nutritional quality and health benefits. The modern trend for the development of new food products aspires for complementary foods to fulfil the widening gap of food availability and nutritional security. Extrusion cooking is used to produce expanded snack foods, modified starch ready-to-eat cereals, baby foods and pasta. This technology has many distinct advantages like versatility, low cost, better product quality and lack of process effluent.

The combination of arrowroot powder and finger millet in the production of gluten-free noodles offers a unique synergy of properties. Arrowroot contributes a smooth texture and neutral taste, while finger millet brings in earthy notes and enhanced nutritional content. The blending ratio becomes crucial in achieving a balance that ensures optimal noodle texture, taste, and nutritional benefits.

This combination aligns with the increasing demand for gluten-free products, catering not only to individuals with gluten sensitivity but also to those seeking diverse and nutritious food options. As alternative flours gain popularity in the food industry, arrowroot and finger millet emerge as promising ingredients that address both dietary restrictions and health-conscious consumer preferences. The utilization of these two ingredients in noodle production reflects a dynamic approach to food innovation, blending traditional ingredients with modern dietary needs.

This research project aimed to develop gluten-free noodles using a blend of arrowroot powder and finger millet powder. The investigation explored the physicochemical properties, sensory attributes, and nutritional profile of the novel noodles. Our findings, consistent with studies on alternative flours (Smith et al., 2018; Patel and Jones, 2020), revealed that the arrowroot and finger millet blend exhibited promising characteristics for noodle production. The noodles demonstrated favorable cooking qualities, acceptable sensory attributes, and a nutritional profile enriched with essential nutrients.

The raw material combination played a critical role in determining the final product's texture, taste, and nutritional content. The inherent characteristics of arrowroot, known for its gluten-free nature and neutral flavor (Chen et al., 2019), complemented the earthy notes and nutritional benefits of finger millet (Gupta and Singh, 2021). The blending ratio was optimized to achieve the desired noodle texture and nutritional balance.

Physicochemical analyses indicated that the gluten-free noodles had comparable cooking time and water absorption properties to traditional wheat-based noodles. The sensory evaluation conducted with a diverse panel of participants reflected overall acceptance, emphasizing the potential marketability of these alternative noodles the utilization of arrowroot and finger millet proved effective in producing gluten-free noodles with desirable attributes. This research contributes to the expanding body of knowledge on alternative flours in the food industry, aligning with the growing demand for gluten-free products. The optimized blend not only addresses dietary restrictions for gluten-intolerant individuals but also offers a nutritious option for the wider consumer base

CHAPTER VI

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ABSTRACT

In recent years, there has been a growing interest in the development of healthier dietary alternatives, particularly gluten-free food products, due to increasing awareness of dietary impacts on overall well-being and the rising prevalence of gluten-related disorders. This thesis focuses on the development and quality evaluation of gluten-free noodles made from arrowroot powder and finger millet powder. The aim is to provide a nutritious and acceptable alternative to traditional wheat-based noodles, catering to individuals with gluten sensitivity or celiac disease and health-conscious consumers.

Arrowroot powder, derived from the Maranta arundinacea plant, is known for its neutral flavour and excellent thickening properties, making it an ideal ingredient for improving the texture and sensory qualities of gluten-free noodles. Finger millet powder, sourced from Eleusine coracana, is rich in essential amino acids, dietary fiber, and minerals, enhancing the nutritional profile of the noodles.

This research involves a comprehensive evaluation of the physicochemical properties, sensory attributes, and nutritional content of the developed gluten-free noodles. The study includes the analysis of texture, firmness, elasticity, cooking qualities, and overall acceptability among consumers. The results indicate that the combination of arrowroot and finger millet powders yields noodles with desirable cooking qualities and sensory attributes comparable to conventional wheat noodles. The optimized formulation achieves a balance between texture and nutritional value, making it a promising alternative for gluten-free diets.

By exploring the potential of these alternative flours, this thesis contributes to the scientific understanding of gluten-free product development and offers practical insights for the food industry. The findings are expected to pave the way for innovative gluten-free noodle formulations, addressing the dietary needs of individuals with gluten-related disorders while appealing to a broader consumer base seeking healthier dietary options. This work aligns with contemporary trends in food science and nutrition, emphasizing the importance of diverse and nutritious gluten-free alternatives in modern diets.