DEVELOPMENT AND QUALITY EVALUATION OF NUTRIENT RICH PASTA FROM COMPOSITE FLOUR

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KERALA, INDIA

2022

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PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree of

Bachelor of Technology

In

Food Engineering & Technology

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

DEPARTMENT OF PROCESSING AND FOOD ENGINEERING

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY, TAVANUR - 679573

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DECLARATION

We, hereby declare that this project report entitled "**DEVELOPMENT AND QUALITY EVALUATION OF NUTRIENT RICH PASTA FROM COMPOSITE FLOUR**" 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.

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CERTIFICATE

Certified that this project report entitled, "**DEVELOPMENT AND QUALITY EVALUATION OF NUTRIENT RICH PASTA FROM COMPOSITE FLOUR**" is a record of project work done jointly by Mr Alan Joseph, Ms Anjaly Balakrishnan, Ms Devika K K, Ms Maya S Kumar, and Ms Stella Johnson 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.

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ACKNOWLEDGEMENT

Any accomplishment requires the efforts of many people, and this work is no different. We find great pleasure in expressing our deep sense of gratitude towards all those who have made it possible for us to complete this project with success.

First of all, we would like to express our true and sincere gratitude to our mentor **Dr Rajesh G K**, Assistant Professor, Department. of Processing and Food Engineering, Kelappaji College of Agricultural Engineering and Technology, Tavanur, for his dynamic and valuable guidance, care, patience, and keen interest in our project work. This project has been a result of the combined efforts of our guide and us. He has been a strong and reassuring support to us throughout this project. We consider it our greatest fortune to have him as the guide for our project work and our obligation to him lasts forever.

With great gratitude and due respect, we express our heartfelt thanks to **Dr Sathian K K,** Dean (i/c), KCAET, Tavanur for his support while carrying out the project work. We engrave our deep sense of gratitude to **Dr Prince M V**, HOD, Department of Processing and Food Engineering, **Ms SreejaR**, Assistant Professor, Department of Processing and Food Engineering, **Er. Anjaly M G**, Assistant professor, AICRP on PHET, and **Er. Shahama**, KCAET, Tavanur.

We express our profound sense of gratitude to **Mrs Jojitha** and **Mrs Geetha**, staff members of the Department of Processing and Food Engineering, KCAET, Tavanur and **Mr Radhakrishnan MV**, Lab Assistant for their immense help.

We express our thanks to all the library staff members, KCAET, Tavanur for their ever-willing help and cooperation. We express our sincere thanks and gratitude to Kerala Agricultural University for providing this opportunity to do the project work.

We are greatly indebted to our parents for their love, blessings, and support which gave strength to complete our study. We also acknowledge our friends for their support and care throughout the project.

Above all, we bow our heads before **God Almighty** for the blessings bestowed upon us which made us materialize this endeavour.

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Dedicated to the

Food Technology Profession

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Abbreviations and Symbols

%	Per cent
&	And
/	per
<	Less than
+	Plus
a*	Greenness or redness
b*	Blueness or Yellowness
CF	Cornflour
cm	Centimetre
CMC	Carboxymethyl cellulose
CPF	Chickpea flour
CRF	Carrot powder/flour
db	Dry basis
Eg.	For example,
et al.	And others
etc.	Etcetera
Fig.	Figure
FMF	Finger millet flour
g	gram
GF	Gluten-free
GG	Guar gum
GI	Glycaemic index

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	:	Beta

CHAPTER I

INTRODUCTION

Food habits and cooking methods are massively changing in the last few years because of urbanization, changes in culture, and social modification. Nowadays, ready-to-eat and ready-to-cook food products have acquired large food markets because it is the closest replacement to our regular food. Ready-to-eat food products in the category of food,that comprisepacked food products,are used for direct consumption without any cooking, whileready-to-cook food products need some preparations like heating or boiling before consumption.Snack foods play a very importantrole in the diet of modern consumers. Many consumers do not have time to prepare traditional meals and lack proper knowledge of cooking. They generally prefer readily available foods after their routine work.

Extrusion technology has a vital role in the production of these kinds of food products in the food industry. Extrusion processing technology is a commonly used processing technology in the food industry with a wide number of applications. It is a processing system that utilizes a single screw or a set of screws to force food materials through a small opening. There are different types of extrusionprocesses, in which hot extrusion and cold extrusion produce ready-to- eat (Eg: flaked cereals) and ready- to cook(Eg: Pasta and dough) products, respectively. Hot extrusion is also known as extrusion cooking in which heating of food is carried out at more than 100℃. In cold extrusion, heating of food is carried out upto 100℃.

Ready to eat cereal based snacks can easily be prepared using extruder. History shows that the first application of the use of a cooking extruder in the foodindustry was for producing an expanded cornmeal-based snack in a single screw extruder. Single screw extruders were first used in the 1940s since twin-screw extruders were not developed for the food industry until the early1980s (Harper, 1981). However, twin-screw extruders are rapidly becomingthe extruders of choice in the food industry.

Consumers are increasingly interested in foods containing healthyingredients. According to Marchylo and Dexter (2001), pasta has an excellent nutritional profile, being a good source of complex carbohydrates and amoderate source of protein and vitamins. Besides being easy to prepare and very versatile food, pasta has a relatively long shelf life when it is storedappropriately. It is also considered an adequate vehicle for foodsupplementation with minerals, proteins, and many other valuable healthycomponents (Borneo & Aguirre, 2008).

Pasta is an ancient foodstuff that is defined as a type of dough, extruded or stamped into various shapes for cooking. It is economical, easy to prepare, has a longer shelf life, and is consumed all over the world in many ways. It is a rich source of complex carbohydrates (74-77%) and protein (11-15%), but it lacks sodium, amino acids, and total fat. The best quality pasta is obtained from durum flour (semolina), produced by milling durum wheat (*Triticum aestivum*) which contains a high level of gluten and produces a final product that is of good quality (Dziki, 2021). Pasta products are normally made from amber durum wheat, i.e., high gluten content, which is milled into semolina and mixed with water, salt, egg, vegetable oil, and at times vegetable colouring. Semolina is preferred to wheat flour because less water is required to make the pasta dough which greatly helps in the drying stage (Bernard, 1988). The variety of products from pasta has increased in part through the addition of vegetable materials which provide different flavours, colours, and often additional nutrients (Banasik, 1981; Matsuo *et al*., 1972). Research into the field of manufacturing and processing pasta, that eliminates the need for cooking for a very long time, has resulted in the production of instant noodles (Kim and De Ruther, 1996). Several researchers have studied theuse of composite flour in noodle making (Sanni*et al*., 2007; Orunkoyi, 2009). Composite flour is the name given to wheat flour, diluted with non-wheat flours like cassava, sweet potato, soybean, maize etc. Noodle snack industries in Nigeria have adopted this method of composite wheat flour as a substitute for whole wheat noodles, thereby reducing the cost of production of noodles and other baked confectionaries. Noodles made from soy flour provide extra protein while carrot provides β-carotene and colour. Various protein sources have been used to increase the protein content of pasta products. Because of the importance of pasta and its consumer acceptance, the textural properties of pasta and noodles have been investigated most extensively (Cole, 1991).

To increase the nutritional quality of pasta made from wheatflour, many studies have been investigated in the addition of ingredients such asamaranth leaf meal, wakame, and germinated *Cajanuscajan* seeds, amongothers (Borneo & Aguirre, 2008). Pasta, with its origin in Italy, has gainedwide popularity as a convenient and nutritionally palatable, low glycemic food. The pasta products have been fortified with supplements from varioushigh-protein sources to improve their nutritional properties.

Milled rice consists of about 90% starch, and the structure of this macromolecular fraction and its physicochemical properties are the primary characteristics used to select rice cultivar and rice starch for specific industrial applications (Bao, 2001). Several studies have been carried out on the physicochemical, morphological, thermal, and rheological properties of rice starch isolated from flour (Singh *et al*., 2006; Vandeputte*et al*., 2003a; Vandeputte*et al.,* 2003b; Vandeputte*et al.,* 2003c). Due to the absence of gluten, rice is recommended as safe for people affected by celiac disease and is commonly used to produce gluten-free (GF) pasta, alone or in combination with other non-gluten cereals and/or additives (Marti *et al*. 2010). There are many types of rice noodles, which are consumed mostly in Asian countries; they are also served in Europe as an alternative to wheat pasta due to their high digestibility, bland taste, and the absence of gluten (Charutigon*et al*., 2008). However, some technical problems can arise in rice paste production due to a lack of gluten, lending the rice pasta a soft texture (Sozer, 2009). Many approaches have been taken for the replacement of gluten in gluten-free starch-based products. These include the use of appropriate substitute ingredients, such as modified starch, pre-gelatinized rice flour, emulsifiers,and protein, suitable for creating a cohesive structure that can overcome the absence of gluten (Chillo*et al*. 2007; Lai, 2001; Sozer, 2009).

Finger millet (*Eleusine coracana),* also called ragi, is an important staple food in eastern and central Africa as well as in some parts of India (Mazumbar*etal.*,2006). In India, finger millet is usually used for the preparation of flour, pudding, porridge, and roti (Chaturvedi & Srivasthava,2008). Finger millets have now gained much popularity because of their functional components, such as slowly digestible starch and resistant starch. It is generally high in calcium and iodine content than other food grains. Ragi has the best quality protein along with the presence of essential amino acids, vitamin A, vitamin B, and phosphorus. Thus, ragi is a good source of diet for growing children, especially women, old age people, and patients. Traditionally, finger millet is processed either by malting or fermentation. Malting of finger millets improves its digestibility, sensory and nutritional qualities as well as pronounced effects in lowering the anti-nutrients. Malting characteristics of finger millets are superior to other millets and rank next to barley malt. Malted and fermented finger millet flour is extensively used in the preparation of weaning food, instant mixes, beverages, and pharmaceutical products (Tripathi*etal*.,2015).

The glycaemic index is a rating system for foods containing carbohydrates. It shows how quickly each food affects your blood sugar (glucose) level when that food is eaten on its own. The low glycemic index is an important factor of a diet for both healthy and diabetic subjects. Generally, seeds of legumes give moderate postprandial blood glucose increase, and Goni and Valentine-Gamezo observed that the addition of chickpea (*Cicer arietinum)* flour decreases the glycemic response of pasta in healthy people. Chickpea (*Cicer arietinum)* seeds are high in protein. Results demonstrated that the combination of wheat and chickpea enhances the level of quality protein in pasta products, as legumes are rich in lysine which is a limiting amino acid in cereals, and cereals are rich in methionine which is a limiting amino acid in legumes. Pasta products that contained chickpea flour have presented a low glycemic response. This can help widen the scope of low GI foods accessible to the consumer (Nilusha*etal*., 2019).

β-carotene is an important precursor of vitamin A and imparts attractive colour to food products. β-carotene may prevent cancer and certain chronic diseases (Sies and Krinsky, 1995). However, β-carotene and other carotenoids are readily oxidized, being affected by the presence of air (oxygen), heat, and light. Several research works have been carried out on instant noodles, including Orunkoyi (2009), all of which establish the other nutritional benefits of instant noodles in terms of carbohydrates, protein, and fibre as well as their improvement.

In many countries, carrot (*Daucus carota L*) is one of the popular sources of vitamins and dietary carotenoids. According to Speizer *et al.* (1999), carrot has gained increased attention over the years due to its richness in antioxidants and beta carotene (pro-vitamin A) activity.

Corn starch, maize starch, or corn flour is the starch derived from corn (maize) grain. The starch is obtained from the endosperm of the kernel. Cornstarch is a common food ingredient, often used to thicken sauces or soups, and to make corn syrup and other sugars. It has medical uses as well, such as supplying glucose for people with glycogen storage disease. Corn starch is used as a thickening agent in liquid-based foods (e.g., soup, sauces, gravies, custard), usually by mixing it with a lower-temperature liquid to form a paste or slurry. It is sometimes preferred over flour alone because it forms a translucentmixture, rather than an opaque one. As the starch is heated, the molecularchains unravel, allowing them to collide with other starch chains to form amesh, thickening the liquid (Zeng *et al*., 2011).

Guar gum or guaran is a galactomannan polysaccharide extracted from guar beans that has excellent thickening and stabilizing properties making it ideal for food industries. It shows an increase in dough yield, greater resiliency, and improved texture and shelf life in baked goods. It also increasesthe thickness of flours. Guar gum decreases the cholesterol level due to its high soluble fibre content. It helps to provide satiety or slow digestion of a meal, thus lowering the glycemic index of that meal. Guar gum is a viscosifier with very favourable rheological properties. It has a useful ability to form breakable gels when crosslinked with boron. This makes it extremely valuable for hydraulic fracturing (Brown & Livesey, 1994).

Thus, the incorporation of ingredients into rice-based pasta could serve to provide a healthy and ready to cook food, especially to the nutritionally compromised section of society. Considering the above facts, a project work was undertaken at KCAET, Tavanur with the following specific objectives:

- To optimize the process parameters to produce nutrient rich pasta.
- Storage studies of nutrient rich pasta from composite flour.

CHAPTER II

REVIEW OF LITERATURE

This chapter gives general information on the ingredients of nutrient rich pasta, their chemical composition, and their effects on the quality of end products. Researches done on these aspects were reviewed and discussed in detail under the following topics.

2.1 EXTRUSION

Food extrusion is a form of extrusion used in food processing. It is a process by which a set of mixed ingredients are forced through an opening in a perforated plate or die with a design specific to the food and is then cut to a specified size by blades. The machine which forces the mix through the die is an extruder, and the mix is known as the extrudate. The extruder consists of a large, rotating screw tightly fitting within a stationary barrel, at the end of which is the die.

Extrusion enables mass production of food *via.* a continuous, efficient system that ensures uniformity of the final product. Food products manufactured using extrusions usually have high starch content. These include pasta, bread (croutons, breadsticks, and flatbreads), many breakfast cereals, ready-to-eat snacks, confectionery, pre-made cookie dough, some baby foods, full-fat soy, textured vegetable protein, beverages, and dry/semi-moist pet foods (Dias *et al*., 2009). Extrusion is classified into hot extrusion and cold extrusion.

2.1.1 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, gelatinizethe starch, polymerizeproteins, 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, plastification, 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).

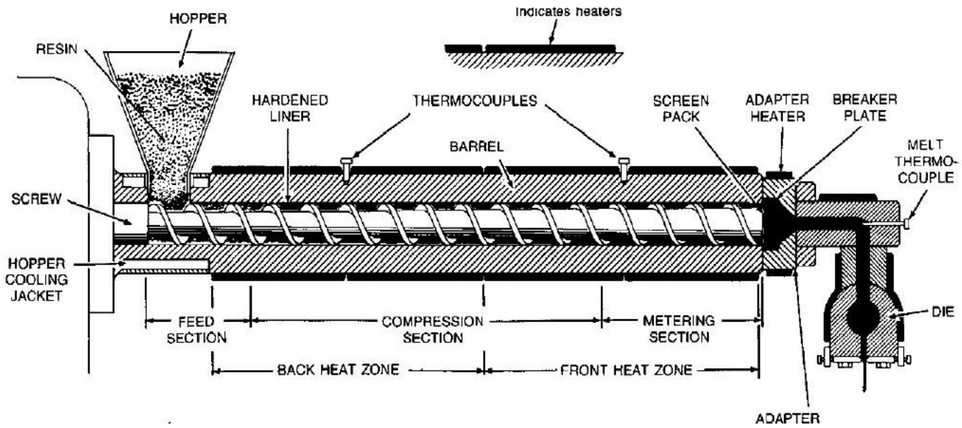

Fig.2.1. Single screw extruder (Ref: Fellows, 2000)

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 for children and mothers. The foods based on 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 snacksand 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.

Sudhadevi (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 hasan impact on the quality 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 utilizedto produce extruded items. By using different types of basic and raw ingredients, the extrusion cooking technology produces several food items for human consumption with various textures, shapes, flavours, and colours. Shelar& Gaikwad (2019) studied the extrusion in the food sector along with extrusion type and the 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.

2.1.2 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. Agnesi*et 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 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 pasta based on corn starch and cornflour. Both plateau modulus and width between different relaxation times showed a positive correlation with the increase of hydrocolloid concentration, reflecting a decrease in the molecular mobility of the matrix.

Bouasla *et al*. (2017) studied the physical properties, texture, sensory attributes, and microstructure of the gluten-free precooked rice pasta enriched with legume flours. This study evaluated selected properties of precooked rice pasta enriched with different levels (10 g/ 100g, 20 g/100g, and 30g/100g) of legume flours (yellow pea, chickpea, and lentil). Chemical composition, physical properties (expansion ratio, minimal preparation time, water absorption capacity, cooking loss, water absorption index, water solubility index, and colour), texture properties (hardness, firmness, adhesiveness), and sensory attributes were evaluated. Results showed that the addition of legume flours decreased the expansion ratio, the hardness, and the lightness, and increased the yellowness and firmness, and adhesiveness, without affecting the minimal preparation time. The gluten-free pasta product had a low cooking loss (<6%) and acceptable scores for sensory attributes and overall quality.

Marengo *et al.* (2018) investigated enriching gluten-free rice pasta with soybean and sweet potato flours. Rice-based pasta was enriched with flours from soybean and orange-fleshed sweet potato, which are common ingredients in the African tradition. They prepared and characterized four different formulations based on pre-gelatinized rice flour, liquid egg albumin, and containing soybean and/ or sweet potato (up to 20%). Soybean and sweet potato enrichment led to a decrease in pasta consistency and insignificant changes in the colour of the resulting samples, likely due to Maillard-type reactions. E-sensing approaches indicated that the sensory profile of the various pasta products strongly depended on the type of enrichment. Data collected after cooking suggests that both soybean and sweet potato have a role in defining the firmness and water absorption, as well as the optimum cooking time.

Arribas *et al*. (2020) determined the cooking effects on the bioactive compounds, texture, and colour properties of cold extruded rice/bean-based pasta supplemented with whole carob fruit. In this study, the content of individual inositol phosphates, soluble sugars, α-galactosides, protease inhibitors, lectin, phenolic composition, colour, and texture were determined in cooked and uncooked pasta. The highest total inositol phosphates and protease inhibitors contents were found in the samples with a higher bean percentage. After cooking, the content of total inositol phosphate and the total protease inhibitors activity increased in values, whereas the competitive enzyme-linked immunosorbent assay (ELISA) showed the elimination of the lectins. By the cooking process, α-galactosides and total phenols contents were found reduced. The cooked samples fortified with 10% carob fruit resulted in darker fettuccine with good firmness and hardness and higher antioxidant activity, sucrose, and total phenol content than the corresponding counterpart without this flour.

Cappa *et al.* (2021) investigated the effects of red rice (R), and buckwheat (B) flour addition on the nutritional, technological, and sensory quality of potato-based pasta. They produced three gluten-free (GF) and three conventional (C) without any addition or with 20% R or B. R and B addition significantly reduced starch content and increased fat amount and ready digestible starch fraction. R addition worsened GF pasta structure by increasing solid loss in cooking water and reducing product firmness. B addition resulted in intermediate consistency despite the highest total fibre content and weight increase during cooking. Similar trends were found in C samples indicating a better texturing capacity for B in comparison to R.

Pasta is a staple food in many countries.Accordingto Marchylo and Dexter (2001), it has an excellent nutritional profile. To increase the nutritional quality of pasta made from wheat flour, many studies investigated the addition of ingredients (Borneo & Aguirre, 2008; Prabhasankar*et al.,* 2009). Pasta is an important source of carbohydrates, but low in sodium, fat, and cholesterol and is considered one of the most consumed foods worldwide.

2.3 RAW MATERIALS

2.3.1 Rice Flour

Lai (2002) investigated the effects of two emulsifiers (distilled glyceryl monostearate and a commercial emulsifier (KM300)) on the pasting and thermal properties of dried rice pasta using a rapid visco analyzer and a differential scanning calorimeter. The rice pasta made from high amylose rice flour had better extrusion properties, better texture, white colour, less cooking loss, and better eating quality than that made from low amylose rice flour. SEM investigations showed that the use of an emulsifier restricted the swelling of starch granules, especially for the pasta made from high amylose rice flour.

Marti *et al.* (2011) conducted experiments for understanding starch organization in gluten-free pasta from rice flour. Starches extracted from parboiled rice flour and pasta samples produced by two extrusion processes- a conventional method carried out at 50°C and an extrusion cooking process at 115°C- were evaluated by differential scanning calorimetry (DSC) and size extrusion chromatography (SCE) analysis. Molecular changes induced by both pasta-making processes following cooking in boiling water were also investigated using iodine absorption properties of samples. A decrease in polymer chain mobility and iodine binding capacity was observed after pasta making process. The pasta-making process also affected the molecular size distribution of starch samples. Moreover, besides the increase in melting temperature, a decrease in endothermic enthalpy was detected.

Barbiroli *et al*. (2013) claimed that the process conditions affect the starch structure and its interactions with proteins in rice pasta. Structural changes of starch and proteins in rice pasta were investigated as a function of raw materials and pasta-making conditions, and their impact on cooking behaviour and the glycaemic index were assessed. The starch structure was studied by assessing starch accessibility to specific enzymes and by evaluating the molecular properties of fragments from enzymatic actions. Parboiling stiffens the protein network in rice flour and makes starch accessible to hydrolysis.

Wang *et al*. (2016) studied the effects of extrusion conditions on the extrusion responses and the quality of brown rice pasta. This research investigated the effects of extrusion temperature and screw speed on the extrusion system parameters and the qualities of brown rice pasta. The die pressure and motor torque value reached a maximum at the temperature of 90°C but decreased when the screw speed increased from 80-120 rpm. The pasta produced at an extrusion temperature of 120°C and screw speed of 120 rpm had the best quality with a cooking loss, hardness, and adhesiveness of 6.7%, 2387.2g, and -7.0 g. s respectively, like those of pasta made from gluten-free flour.

Phongthai *et al.* (2017) reported the effects of protein enrichment on the properties of rice flour-based gluten-free pasta. The whey protein concentrate (WPC) enriched pasta demonstrated the shortest optimal cooking time at 4.3 minutes. The enrichment of 9% (w/w) egg albumen displayed the greatest capacity for preventing structure disintegration for the lowest cooking loss of 4.38-4.63% whereas rice bran protein concentrate induced the highest cooking loss. Among the four sources of protein tested, egg albumen had the highest potential for improving the cooking properties of rice-based gluten-free pasta.

Detchewa *et al*. (2022) claimed that the substitution of rice flour with rice proteins improved the quality of gluten-free rice spaghetti processed using single screw extrusion. Rice protein was used to improve the cooking quality, physicochemical properties, and sensory attributes of gluten-free rice spaghetti (GFRS). GFRS samples were developed by replacing rice flour with rice protein concentrate at 0%, 2.5%, 5.0%, 7.5%, and 10% (w/w), processed through a single screw extruder. Substitution of rice flour with 5%-10% rice protein significantly decreased cooking time and cooking loss. GFRS with 5%-10% RP was more porous than GFRS without RP. Sensory evaluation showed that GFRS containing 2.5 % and 5% RP had a high overall linking score.

2.3.2 Chickpea

Goni *et al*. (2002) did studies on pasta containing chickpea flour as an ingredient. The objective of the work was to make a common type of pasta (spaghetti) using chickpea flour as an ingredient to achieve a nutritious, slowly digestible food, rich in dietary fibre and starch to diversify the range of available foods with low glycaemic response. It was determined that the incorporation of chickpea flour increased the quality of protein, mineral, and fat contents of pasta thus contributing to the elevation of the nutritional quality of food. Chickpea flour also reduced the hyperglycemia peak and total hyperglycemia phase.

Osorio-Diaz *et al*. (2009) investigated the chemical composition, in-vitro starch digestibility, and predicted glycaemic index of pasta added with chickpea flour. This study evaluated the influence of these factors on composite legume-wheat pasta. Cooked spaghetti elaborated with semolina and chickpea flour exhibited increased protein, ash, lipid, and dietary fibre contents while decreased total starch levels compared to durum wheat control pasta. The available starch content decreased whereas the resistant starch level increased with the addition of chickpea flour. Also, moderate predicted glycaemic indices were found for chickpea-added products. The data suggest that pasta added with chickpea flour may be an alternative for people with special caloric or metabolic requirements.

Lima *et al*. (2019) conducted a study to develop pasta dough utilizing only chickpeas as a flour source and to analyze its chemical, technological and sensory characteristics. The chickpea pasta presented 37.3% less fat, 53.8% more protein, and 166.5% more dietary fibre. It also presented good acceptance for every criterion including texture and taste.

El-Sohaimy *et al*. (2020) studied the physicochemical, texture, and sensorial evaluation of pasta enriched with chickpea flour and protein isolate.

Eight fortified pasta products were prepared of durum semolina wheat with partial replacements of 2.5, 5, 7.5, and 10% of chickpea flour or chickpea protein isolate (PI). Both fortifications decreased optimum cooking time and starch content with overall increases in cooking losses, swelling index, hardness, cohesiveness, springiness, gumminess, and doubled the chewiness, also resulting in higher moisture cooked pasta.

Saget *et al*. (2020) reported substituting wheat with chickpea flour in pasta production delivers more nutritious at a lower environmental cost. They performed a life cycle assessment to compare the environmental footprint of pasta made from chickpea with conventional pasta made from durum wheat. Cooked chickpea pasta contains 1.5 more protein, 3.2 times more fibre, and 8 times more essential fatty acids than cooked durum wheat pasta per kcal energy content.

Suo *et al.* (2022) studied the effects of chickpea flour and its addition levels on the quality and *in-vitro* starch digestibility of corn-rice-based gluten-free pasta. This work aims to fortify multi cereal (corn-rice) gluten-free (GF) pasta with chickpea. Chickpea significantly increased pasta protein and dietary fibre contents to a level that supports the high fibre/protein contain claims. Chickpea addition induced darkening, softening, adhesiveness decrease, and solid loss reduction compared to the control. In addition, chickpea substitution significantly modified the invitro starch digestion.

Table 2.3.1 Nutrition facts of chickpea

Contents (grams)	**Chickpea**
Energy(kcal)	269
Carbohydrate	45
Protein	14.5

Fibre	12.5
Fat	4

2.3.3 Carrot Powder

Adegunwa *et al.* (2012) studied the enrichment of noodles with soy flour and carrot powder. Noodles were produced from four flour blends, and these were analyzed for proximate analysis, functional properties, and total carotenoid content. The study revealed that the sample with carrot flour produced a noodle with attractive colour and increased vitamin A content. The protein content of soy flour is appreciably high.

Jalgaonkar *et al.* (2017) conducted a study on the influence of incorporating defatted soy flour, carrot powder, mango peel powder, and moringa leaves powder on the quality characteristics of wheat semolina- pearl millet pasta. Cooking time decreased from 8.01 to 5.38 minutes and cooking loss increased from 8.0% to 11.90%. Sensory evaluation revealed that samples were within the acceptable range. Maximum incorporation of 15% defatted soy flour, 10% carrot powder, 5% mango peel powder and 3 % moringa leaves powder was found suitable in terms of colour, cooking loss, hardness, and sensory quality.

Sule *et al.* (2019) made a study on the effect of carrot powder incorporation on the quality of pasta. This study showed that the physical characteristics of pasta were affected by carrot incorporation. The study has shown that acceptable and micronutrient enriched pasta can be produced from wheat flour incorporated with carrot powder upto 30%. It increased the vitamin content and overall acceptability of pasta.

Sharma *et al.* (2021) investigated developing enriched pasta by utilizing vegetables (spinach and carrot) powders (6-18%) and millet (pearl millet and sorghum) flours (10-30%) to increase the iron and vitamin A contents. More than 95% retention was observed for both the micronutrients at each level of variable plant source enrichment. Fortified pasta was acceptable after 4 months of storage with minor changes in moisture and fatty acid contents.

Table 2.3.2 Nutrition facts of carrot

Contents (grams)	**Carrot (100 g)**
Energy(kcal)	41
Carbohydrate	9.6
Protein	0.9
Fibre	2.8
Fat	0.2
Sugar	4.7
Water	88%

2.3.4 Finger Millet

Tripathi *et al.* (2015) developed value-added pasta with the incorporation of malted finger millet flour. The objective of this study was to utilize malted finger millet to produce tasty and nutritious pasta. It was concluded that the incorporation of malted finger millet improved the antioxidant and nutraceutical properties of pasta by increasing the content of calcium and iron. It also increased the overall acceptability of newly formed pasta.

Lande *et al.* (2017) produced nutrient-rich vermicelli with malted finger millet flour. This study aimed at the production of vermicelli using malted finger millet and conducting nutrient and sensory evaluation of the product. The use of finger millet in vermicelli improved crude fibre content, iron, and calcium content by four, three, and six-fold respectively withthe addition of ragi flour up to 30% in wheat flour. It also showed more acceptance based on sensory parameters.

Hymavathi *et al.* (2019) attempted to prepare nutrient-rich noodles with blends of finger millet and wheat flour along with various hydrocolloids to improve the cooking quality of noodles. Results revealed that the addition of hydrocolloids showed improvement in the cooking and textural parameters of noodles. These noodles were significantly rich in nutrients compared to wheat noodles.

Virk *et al.* (2019) studied the development of gluten-free processed products i.e., cookies and pasta by incorporating gluten-free ingredients in different proportions. The gluten-free raw ingredients i.e., finger millet, pearl millet, soybean, and groundnut were assessed for their nutritional characteristics. Results of the nutritional analysis concluded that these ingredients are a rich source of crude fibre, protein, fat, and ash or mineral content.

Kumar *et al.* (2020) investigated to verify the potential of extruded finger millet flour in improving the rheological, technological, nutritional, and sensory characteristics of pearl millet-based composite dough and flatbread. Incremental addition of extruded finger millet in pearl millet composite dough caused a significant decrease in pasting properties of composite dough whereas there was a significant increase in dough extensibility. Extruded finger millet flour significantly improved the puffing, textural and nutritional quality of pearl millet composite flatbread. Substation of extruded finger millet flour significantly improved the technological properties and nutrition of pearl millet-based flatbread.

Patil andSawant (2012) studied the nutrition facts of ragi and compared it with othergrains. It has been tabulated in Table 2.3.3

Table. 2.3.3 Nutrition facts of cereals

Contents (grams)	Brown Rice	Wheat	Maize	Ragi
Energy(kcal)	362	348	358	336
Carbohydrate	7.9	11.6	9.2	7.7
Protein	7.9	11.6	9.2	7.7
Fibre	1	2.2	2.8	3.6

2.3.5 Corn Starch

Chillo *et al*. (2007) studied the effect of carboxymethylcellulose and pregelatinized corn starch on the quality of Amaranthus spaghetti. This work aimed to compare the effects of two gluten substitutes, carboxymethyl cellulose sodium salt and pregelatinized corn starch, both used in 3 % on the quality of gluten-free spaghetti in the base of Amaranthus flour. Spaghetti with CMC had a cooking loss compared with control, while for spaghetti containing PCS, the cooking loss values were higher than that of control. All spaghetti with CMC presented better cooking resistance concerning control and that of spaghetti with PCS.

Ditudompo *et al.* (2016) studied the effect of extrusion conditions on expansion and selected physical characteristics of corn starch extrudates. Three response parameters (apparent density, porosity, and expansion ratio) were examined for investigating the expansion characteristics of cornstarch as a function of extrusion conditions. The results were used to optimize process conditions, which can minimize production loss and provide information for controlling or predicting textural characteristics of expanded corn starch products.

Dib *et al*. (2018) tested the effect of hydrothermal treatment of cornflour on its applicability as a gluten-free pasta improver. Results showed that hydrothermal treatment of corn flour affected in different extends on pasta properties, improving the cooking and textural characteristics of pasta. The addition of treated flour induced significant differences in all parameters in comparison with controlled pasta.

Ainsa *et al.* (2021) developed gluten-free pasta enriched with fish byproducts for special dietary uses. For this purpose, four optimal formulations, obtained with an iterative process, were analyzed to determine the effects of different ingredients (yellow corn flour, white corn flour, and rice flour) in gluten-free pasta compared to commercial wheat pasta. The enriched gluten-free pasta required a shorter cooking time and was characterized by lower hardness, springiness, gumminess, chewiness, and fracturability, and had higher values of adhesiveness than wheat pasta. The incorporation of yellow corn gives gluten-free pasta a similarity in colour to commercial pasta.

Bresciani *et al.* (2021) attempted to incorporate high amylose corn in gluten-free pasta to deliver nutritional benefits ensuring the overall quality. High amylose corn or in combination with conventional corn was used to produce gluten-free pasta. Resistant starch, soluble and cell wall-bound phenolic acids, and antioxidant capacity were significantly higher in high amylose corn pasta.

2.3.6 Guar Gum

Guar gum also called guaran is a galactomannan. It is primarily the ground endosperm of guar beans. The guar seeds are dehusked, milled, and screened to obtain the guar gum. It is typically produced as a free-flowing, off-white powder. Chemically guar gum is a polysaccharide composed of the sugars galactose and mannose. The backbone is a linear chain of β 1,4- linked mannose residues to which galactose residues are 1,6-linked at every second mannose, forming short side branches. Guar gum, as water-soluble fibre, acts as a bulk-forming laxative, so is claimed to be effective in promoting regular bowel movements and relieving constipation and chronic related functional bowel ailments, such as diverticulosis, Crohn's disease, colitis, and irritable bowel syndrome. Guar gum has been considered of interest in both weight loss and diabetic diets. It is a thermogenic substance by Brown & Livesey (1994). Moreover, its low digestibility lends its use in recipes as filler, which can help to provide satiety, or slow the digestion of a meal, thus lowering the glycaemic index of that meal.

Sandhu *et al.* (2014) studied the effect on processing and cooking quality of pasta containing nontraditional ingredients and guar gum (GG). The results from mixograms indicated that GG increased the dough strength of durum flour. It was also noted that guar gumdid not affect the cooking quality of pasta.

Aminullah *et al*. (2020) studied the effect of guar gum addition on the physical quality of the extruded dry corn noodle made from a mixture of wet and dry corn flour. The result showed that the optimum dehydration time for dry corn noodles was about 9 minutes. An increase in guar gum levels tended to increase the elongation of dry corn noodles and reduced the stickiness and cooking loss.

Devi *et al.* (2021) developed rice-based composite pasta with improved cooking or rehydrating and nutritional qualities. Pasta samples having different proportions of rice flour, wheat flour, malted green gram flour, and guar gum were prepared using a single screw extruder. Substitution of wheat flour with rice flour significantly reduced the cooking time and improved the whiteness and yellowness indices of the samples. Reduction in wheat flour increased cooking loss. Nevertheless, the addition of guar gum and malted green gram flour reduced these losses and improved sensory qualities.

Getachew &Admassu (2020) developed pasta from Moringa leaves- oat-wheat composite flour and evaluated the effect of blending proportion of the individual flour on the physico chemical properties and sensory qualities of pasta products. Increasing in the levels of moringa leaves powder showed in increasing of proximate composition, however, reduced in moisture content of pasta.

Karigidi&Olaiya (2022) studied the effect of *Curculigo Pilosa* substitution on nutritional quality of yam flour and invitro digestability and sensory analysis of pasta. Proximate analysis showed that crude protein, crude fat and crude ash were significantly increased in the composite flour. Also, important mineral elements and some essential amino acids are increased significantly in composite flours 5 and 10% *Curculigo Pilosa.* The invitro digestibility of carbohydrate of the pasta made from composite flour decreased while that of protein increased significantly.

2.4 PHYSICAL PROPERTIES

2.4.1 Colour characteristics

Iwe*et 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 recipe increased. In general, dry pasta containing legume flours had a significantly more yellow colour than dry rice pasta.

2.4.2 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.

2.4.3 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.

2.5COOKING CHARACTERISTICS

2.5.1 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 semolinawere 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.

2.5.2 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.

2.5.3 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).

Surasani*et 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.

2.6 NUTRITIONAL CHARACTERISTICS

2.6.1 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.

Bouasla*et 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 productswere 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.

2.7 SENSORY CHARACTERISTICS

Hanne *et al.* (2005) studied the sensory quality of extruded oat, stored in light and darkness in packages with different oxygen transmission rates (including the use of an oxygen absorber), which was evaluated after 3 months of storage at 38˚C and 10 months of storage at 23˚C. To reduce the costly and time-consuming shelf life and packaging evaluation, the possibility of reducing the number of sensory attributes to be analyzed and of accelerating shelf-life testing was studied. The intensity of oat odour, paint odour, and crispiness was found to describe the main differences among the samples. By increasing the temperature from 23 to 38˚C for samples stored in darkness, packaging evaluation tests for extruded oat might be performed in approximately one-third of the time. Changes in headspace oxygen concentration in the packages due to oxygen consumption agreed with the sensory changes in the oat.

Min-arovicova*et al*. (2018) reported that at high enrichment levels the sensory properties were ingredient and dose-specific, giving to the reduction of sensorial pasta attributes such as grain taste and pasta. These by-productswerecharacterized by brown colour and pleasant vegetable flavour.

Pan *et al.* (2018) claimed that the consumer's sensory evaluation of pasta enriched with soy okra in form of powder revealed that the inclusion of up to 10% significantly reduced the scores that the consumers gave in terms of colour, flavour, texture, and overall pasta acceptability. Instead, the inclusion of 5% did not show any significant difference between those and the control. However, consumers showed a higher preference for the pasta obtained at 5% and 10% fortification levels with the simultaneous inclusion of vital gluten, often used to improve deficiencies viscoelastic properties.

Cappa *et al.* (2020) reported that the texture properties of both conventional and gluten-free formulations added with buckwheat should be improved by reducing particle size thus making the matrix more uniform and palatable. Great attention must be paid to the particle size of wholemeal buckwheat as a high number of particles produces a negative sensation in the consumers, thus reducing the product's acceptability.

2.8 STORAGE STUDIES OF PASTA

Gull et.al (2017) studied the storage stability of millet pomace based functional pasta in two different packaging materials LDPE (low density polyethylene) and BOPP (bioxially oriented polypropylene) at accelerated condition. Quality parameters like moisture content, total plate count, firmness, cooking loss and color of developed functional pasta was evaluated at an interval of one month during four months of storage period.

Kamble et.al (2020) examined the storage stability of multigrain pasta by packing in high density polyethylene (HDPE) and biaxially oriented polypropylene (BOPP) films under ambient (28 ℃, 65% RH) and accelerated conditions (38℃, 90% RH). The packaged product was analysed for changes in biochemical parametersover a storage period of 4 months. The potential shelf life of HDPE packed pasta stored at a 28℃ and 38℃ was 8.12 and 2.48 months, respectively, whereas for BOPP packaged sample, it was 5.15 and 1.87 months respectively.

CHAPTER 3

MATERIALS AND METHODS

This chapter deals with the methodologies used for the development of nutrient rich pasta from composite flour (rice flour, carrot powder, chickpea flour, and finger millet 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 carrot, chickpea, finger millet, corn flour, rice flour and guar gum.

3.2 PREPARATION OF SAMPLE

Good quality carrot, finger millet, chickpea flour, cornflour, rice flour, and guar gumwereprocured from the market at Tavanur. Of these, carrot and finger milletwere further processed to obtain the respective flours. These materials were then subjected to preliminary treatments.

3.2.1 Carrot Flour

Carrots obtained were peeled, sliced or grated, and dried to an almost brittle consistency at a temperature of 60°Cin a cabinet drier. The dried brittle carrot was then milled into powder using a pulverizer.

3.2.2 Finger millet Flour

Finger millets obtained were soaked for 16 hours and allowed to germinate (48 hours). The germinatedfinger milletwas 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.

Carrot flour and finger millet flour were then blended with chickpea flour, corn flour, rice flour and guar gum in different proportions.

3.3EXTRUSION PROCESS

A single screw extruder La Monferrina Dolly 10D044 (Plate 3.1) was selected for the preparation of pasta. 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.

Plate 3.1 Single screw extruder

FLOW CHART FOR PRODUCTION OF NUTRIENT RICH PASTA

Raw materials (In different combinations as defined)

Kneading (15, 20, 25 min)

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

Extrusion

Drying (60° C,3hrs.)

Nutrient rich Pasta

Fig 3.1 Flow Chart of PastaPreparation

3.3 OPTIMIZATION OF PROCESS PARAMETERS

3.3.1 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 macronutrientsneeded in large amounts. Vitamins and minerals constitute the micronutrients required in small amounts. Carbohydrates are the major source of 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 nutrient rich pasta was prepared with rice flour as the main ingredient along with cornflour, since they are a rich source of carbohydrates. For meeting protein requirements, chickpea flour was selected. Ragi hasthe best quality protein along with the presence of essential amino acids, vitamin A, vitamin B, and phosphorous. Carrot serves as the vitamin source and guar gum is used as a binding agent. The ingredients weretaken in a ratio to meet the dietary requirementsoptimized. Since chickpea provides more dough strength than finger millet, three different chickpea concentrations (10%, 15%, and 20%) were selected in this study and the feed composition was based on the quality evaluation of the pasta product.

3.3.2 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. Three different kneading time viz. 15min, 20min, and 25min were selected in this study and the time was optimized based on product quality.

3.3.3 Moisture content

Moisture content is simply how much water is in a product. It influences the physical properties of a substance. 3 different moisture content (25%, 30%, and 35% wb) were selected in this study.

Based on the preliminary trials conducted with these treatments five samples were selected and the details are given below:

Table 3.1. Composition of composite flour for pasta production

Sample	Ingredients						KT (Min)	Water Content(%)
	RF (%)	CF (%)	CPF (%)	FMF (%)	CRF (%)	GG (%)		
1	40	20	15	10	10	5	15	35
2	40	20	15	10	10	5	25	35
3	40	20	15	10	10	5	20	25
4	42	21	10	11	11	5	20	30
5	38	18	20	9	9	5	20	35

RF – Rice flour CF- Corn flour

CPF- Chickpea flour FMF- Finger millet flour

CRF- Carrot flour GG- Guar gum

KT- Kneading time

Plate 3.2 Ingredients: Rice flour + corn flour, chickpea flour, finger millet flour, carrot powder & guar gum

Of these, best sample was selected based on the quality of the extruded products. The best sample was only considered for shelf-life studies.

Plate 3.3 Infrared moisture meter

3.4 QUALITY EVALUATION

3.4.1 Physical Properties

3.4.1.1Colour

Product colour is a strong indicator of the thermal history within theextruder. Hunter lab colorimeteris used for the measurement of colour. It works on the principle of focusing the light and measuring theenergy 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 representslight-dark spectrum with a range from 0 (black) to 100 (white), the green-redspectrum with a range from - 60 (green) to + 60 (red) and the blue - yellow spectrum with a range from - 60 (blue) to + 60 (yellow) dimensionsrespectively (Ali *et al*., 2008).

Plate 3.4 Hunterlab Colorimeter

3.4.1.2 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.

Plate 3.5 Water activity meter

3.4.1.3 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)

Plate 3.6 Digital vernier calliper

3.4.2 Cooking characteristics

3.4.2.1Optimum cooking time

Optimum cooking time is measured using the manual method bypressing theproduct between fingers periodically at 1-minute intervals. Whentheproduct was completely soft, the time was noted.

3.4.2.2 Swelling power

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

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

3.4.2.3 Solid loss

It was determined by cooking pasta in boiling water for 20 minutes. After cooking, the cooked materials were retained. The whole filtrate wastransferred 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

3.2.7 Sensory evaluation

Sensory quality is a combination of different senses of a perception coming into play in choosing and eating food. Appearance, flavour, and mouthfeeldecide the acceptance of the food. Sensory analysis was done by consuming the product by a sensory panel (Aneesa *et al.*, 2009). The sensory assessments were conducted from the selected six samples. Sensory characteristics of the extrudates were analyzed based on appearance, colour, flavour, and texture. Sensory score card is given in AppendixI.

3.3 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.

3.3.1 Moisture content

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

3.3.2 Carbohydrates

Estimation of total carbohydrateswas done by the anthrone method. Carbohydrates werefirst hydrolyzed into simple sugars using dilute HCl. In a hot acidic medium, glucose was dehydrated into hydroxymethylfurfural. This compound reacts and forms a green-coloured product with an absorption maximum of 630 nm (Layne, 1975).

Amount of carbohydrate (100mgof sample) = $\frac{mg\ of\ glucose*100}{The\ volume\ of\ test\ sample}$ ....(4)

3.3.3 Protein

The amount of protein present was calculated from the nitrogen concentration of the food, which is considered a standard method of determining protein concentration.A conversion factor(F) is needed to convert the measured nitrogen concentration to protein concentration, in the Kjeldahl method (Saez-Plaza *et al.*, 2013).

The Kjeldahl method is divided into 3 steps: digestion, neutralization, and titration.

The following equation can be used to determine the nitrogen concentration of a sample that weighs m grams using xM HCl acid solution for titration:

% Nitrogen = $\frac{X\ moles}{1000cm^3} * \frac{(V_S - V_B)cm^3}{mg} * 14g * 100$……………….………………(5)

3.3.4 Fat content

Lipid is soluble in organic solvent and insoluble in water, because of this, organic solvents like hexane, petroleum ether etc.can solubilize fat, and fat was extracted from food in combination with the solvent. Hexane is the most used organic solvent for the extraction of fat. Later the fat was collected by evaporating the solvent (AOAC, 1980). Almost all the solvent was distilled off and can be reused.

3.3.5 Ash content

A high-temperature muffle furnace capable of maintaininga temperature between 500-600°C was used for determining ash content. Water and other volatile materials were vaporized, and organic substances wereburned in the presence of oxygen in the air to CO_2, H_2O, and N_2. The weight of the crucible with the sample was noted before and after burning (AOAC, 1980). The percentage of ash werecalculated using the equation:

Percentage of ash = $\frac{(W2 - W1) * 100}{W3}$ …………….…………………….(6)

W_1 =Weight of crucible

W_2 = Weight of crucible with ash

W_3 = Weight of sample

3.4 SHELF-LIFE STUDIES

The shelf life of food can be defined as the time within which the food is safe to consume and has an acceptable quality to consumers.

Shelf-life studies of the nutrient rich pastawerecarried out using the packaging material low density polyethylene (LDPE) of thickness 80 micron. The optimally produced pasta samples were stored for 3 months at ambient conditions. The stored products were periodically analysed at every 15 days interval in terms of quality, nutritional, and sensory parameters.

CHAPTER 4

RESULTS AND DISCUSSIONS

This chapter deals with the results and discussions of the experiments conducted for the development of nutrient pasta from composite flour viz. rice flour, corn flour, chickpea, finger millet, carrot powder and guar gum. The storage studies of the optimally produced pasta 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.

Table 4.1. Hunter lab colorimeter values of the cooked and uncooked sample

Treatments	Uncooked			Cooked		
	L*	**a***	**b***	**L***	**a***	**b***
Control	72.29	-4	29.25	79.07	-5.25	30.71
Sample 1	52.32	6.24	19.69	46.87	5.90	13.98
Sample 2	50.63	6	18.49	44.23	5.76	13.93
Sample 3	39.19	6.11	16.10	46.62	6.46	15.19
Sample 4	45.24	5.70	16.76	42.54	6.18	13.93
Sample 5	42.96	6.01	17.05	51.35	5.44	15.04

From table 4.1 it is observed that L* value of cooked pasta sample ranged from 42.54 to 51.35. The maximum L* value of 51.35 was obtained for sample 5 whereas minimum value of 42.54 was obtained for sample 4. The a* and b* value of cooked pasta ranged from 5.44 to 6.46 and 13.93 to 15.19, respectively.

The difference in the colour characteristics of all pasta samples may be attributed due to differences in the coloured pigments of different flours (Iwe*et al*., 2000). Carini *et al*., (2010) observed decreased L* value and drastically increased a* and b* values with the addition of carrot-based ingredients.

4.1.2 Elongation

Elongation is the state of being elongated or lengthened. Elongation is defined as the length at breaking point expressed as a percentage of its original length.

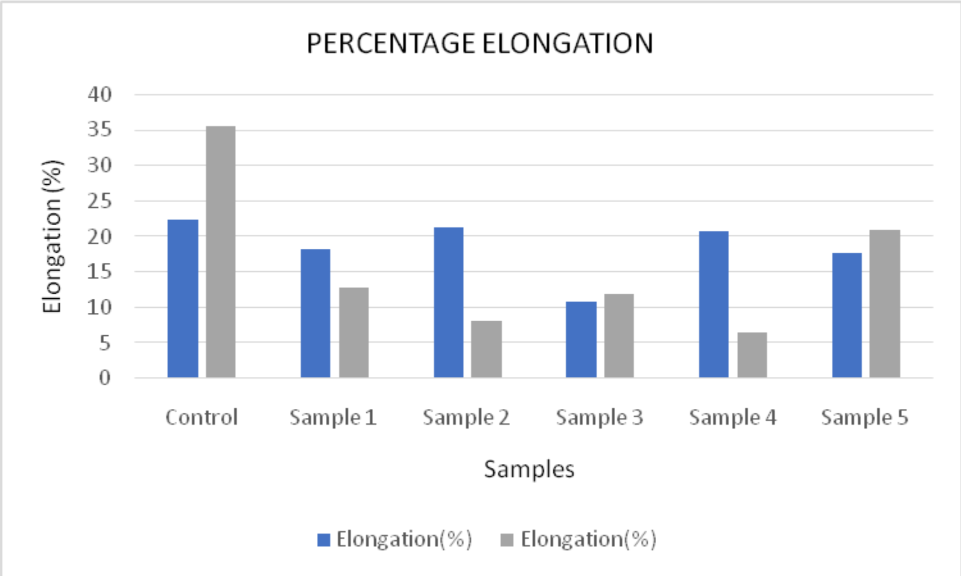

Fig 4.1 Percentage elongation of samples

According to the fig 4.1, percentage elongation of the sample ranged from 21.2% to 10.3% and 20.87% to 7% in terms of length and thickness, respectively. Maximum elongation (length) was obtained for sample 2 and minimum elongation (length) for sample 3. Sample 5 had the maximum elongation in terms of thickness whereas sample 4 had the minimum elongation in terms of thickness.

Moreover, pasta dough enriched with legume flours tended to be more viscous than those with rice flour and therefore, the pressure differential between the value generated by the die and the atmospheric pressure was smaller for enriched pasta, causing a reduction in the expansion ratio (Singh *et al.*, 2007).

4.1.3 Water Activity

Water activity of a food is the ratio between the vapour pressure of the food itself when in a completely undisturbed balance with the surrounding air media and the vapour pressure of distilled water under identical conditions.

Table 4.2 Water activity of Cookedpasta

Sample	Water Activity
Control	0.8
Sample 1	0.892
Sample 2	0.891
Sample 3	0.868
Sample 4	0.869
Sample 5	0.842

Table 4.2 showed that the water activity of cooked pasta ranged from 0.892 to 0.842. Maximum water activity of cooked pasta was obtained for 1st sample whereas minimum value was obtained for 5th sample. From the table, it is understood that the composition of pasta has not much significant effect on water activity.

4.2 COOKING QUALITIES

4.2.1 Optimum cooking time (OCT)

The ideal or optimal time of cooking food is defined by the required time to fully hydrate food. Ideal cooking time is an important factor for pasta.

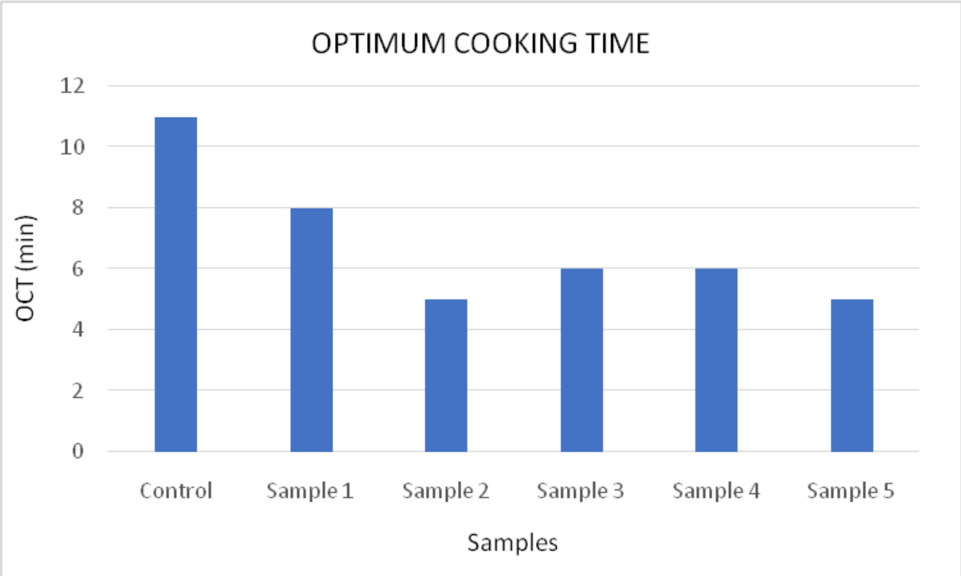

Fig 4.2 Optimum cooking time required for the samples

From the fig 4.2, optimum cooking time of the samples ranged from 5 to 8 min. Maximum OCT was obtained for sample 1 whereas minimum value was obtained for sample 2 and sample 5. Compared to wheat-based noodles, rice noodles have lower cooking time due to the pre-gelatinization of rice flour and higher water absorption index (Raina,2005).

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). Legume proteins denaturation during hot water hydration caused increased accessibility for a polar amino acid group of proteins, this could increase affinity for water and therefore higher water absorption capacity (Alonso *et al.*, 2000). Fig 4.3 shows the swelling power of the pasta samples.

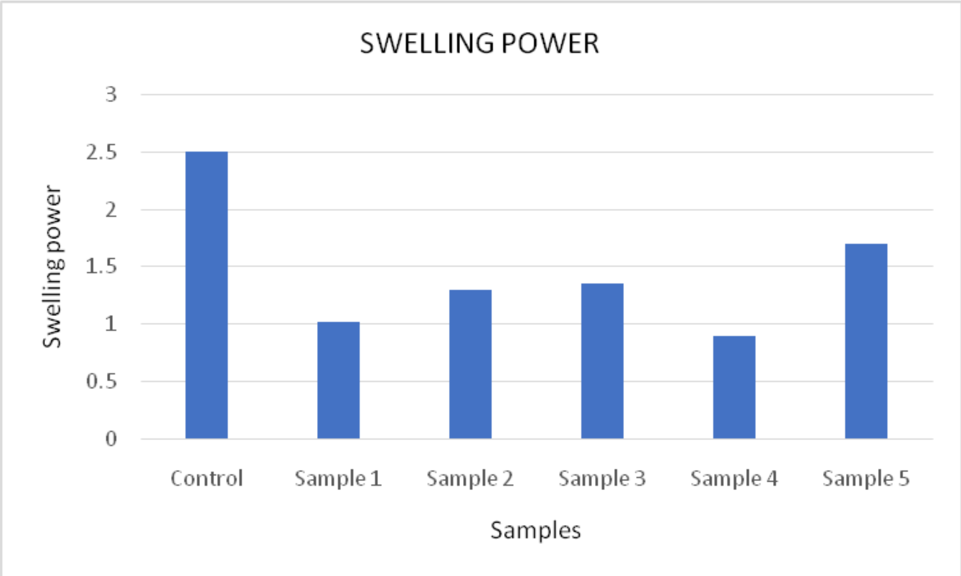

Fig 4.3 Swelling power of samples

4.2.3 Solid loss

Cooking loss is a measure of the amount of solid lost in 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 gradually increased with the increased amount of chickpea and finger millet from 4% to 8%. The increase in cooking loss observed can be attributed due to the absence of gluten protein in these flours (Bhaskaran *et al*., 2011). Also, since the gluten protein network is responsible for retaining pasta'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 increased with an increasing amount of yellow pea flour, chickpea flour, and red lentil flour. 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 pasta, indicating the good quality of all pasta samples (Kim *et al*., 1996; Wang *et al*., 1999).

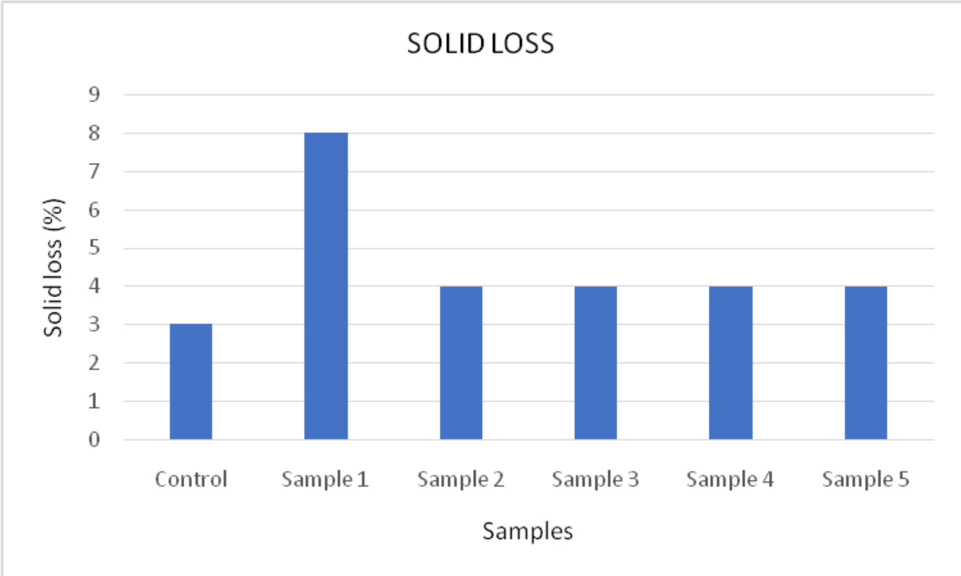

Fig 4.4 Total solid loss in samples

4.3 OVERALL ACCEPTABILITY

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' attitudes (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 viz. colour, taste, texture, and overall acceptability were represented in Appendix 1.

Sensory evaluation was carried out by a panel of 15 judges from the Department of Processing and Food Engineering by giving them a scorecard. Pasta 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 are presented in fig 4.5, and the texture of sample 5 was chosen as the best because of the presence of guar gum. The overall acceptability was higher for sample 5consisting of 20% chickpea. Based on the results from the analysis of cooking quality, colour, texture, and sensory evaluation, it is recommended that 20 % chickpea, 38% rice, 18% cornflour, 9 % finger millet, 9 % carrot powder and 5% guar gum is better to get the best product, which could be an alternative to the unhealthy pasta available in the market. Plate 3.6 shows the optimized sample. Proximate analysis of the optimised sample was done to find the chemical composition. This optimised samplewas packed in low-density polyethylene packs and further analysis for nutritional composition and storage studies were done.

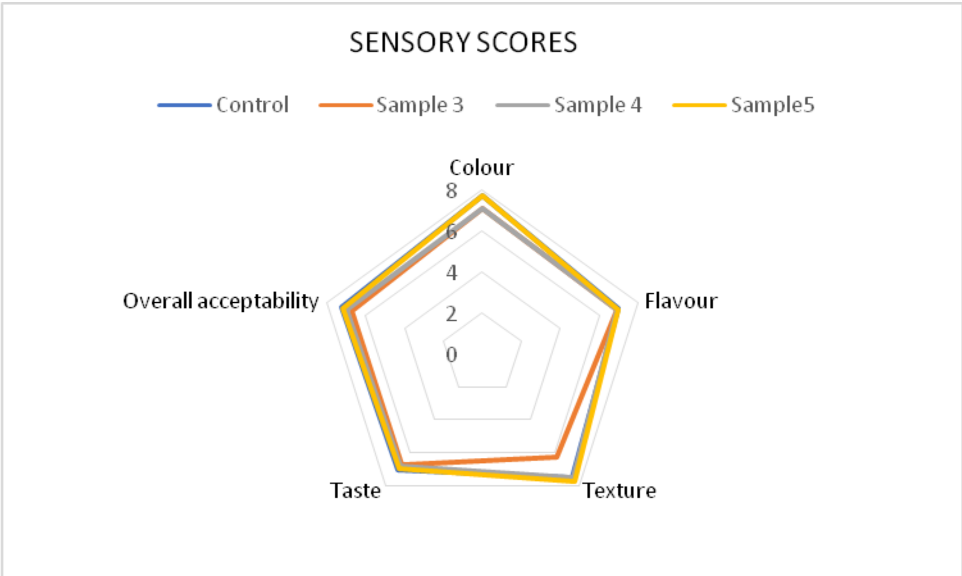

Fig 4.5 Sensory scores of pasta samples

Plate 4.1 Samples for sensory evaluation

Plate 4.2 Optimised Sample

4.4 NUTRITIONAL ANALYSIS

The calorie demands of the human body are mainly supplied by 3 dietary macronutrients: carbohydrates, fat, and protein (Shan *et al.*,2019). The carbohydrate, protein and fat content per 100g of optimized pasta sample was found to be 35, 5.22 and 1.78 g, respectively. From the results of proximate analysis, it is clear that the amount of carbohydrates, protein, and fat present in 100 g of pasta suits the required level for a healthy balanced diet.

Table 4.4.1 Nutrient Analysis report of pasta- Fresh

Sl.No.	Parameter	Result
1	Carbohydrates (g/100g)	35.0
2	Protein (g/100g)	5.22
3	Fat (g/100g)	1.78

4.5SHELF-LIFE STUDIES

Shelf-life studies of optimized pasta samples packed in low-density polyethylene weredone for a storage period of 3 months.

The quality analysis were carried out for the stored sample every 15 days interval. After three months of storage, the stored sample exhibit minimum quality changes in terms of color values, percent elongation, optimum cooking time, swelling power and solid loss. Low water activity value of 0.6 indicated that the sample had a better storage life.

Plate 4.3 Extruded pasta samples

CHAPTER V

SUMMARY AND CONCLUSION

Food is consumed in combinations. The synergy between foods with others 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 between 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.

Pasta should never remain a luxury convenience food of the urban elite. It should also serve the purpose of being the best nutritional alternative for the common man. Hence an economic functional pasta formulation has turned out to be the need of the hour.

Nutrient rich pasta was developed using flour such as rice flour, cornflour, chickpea flour, finger millet flour, and carrot powder as the main ingredients. The present work was carried out to optimise the process parameters and to analyse the quality of the product. Based on the preliminary trials conducted, five samples were selected and its quality evaluation was conducted. L* value of cooked pasta sample ranged from 42.54 to 51.35. The maximum L* value of 51.35 was obtained for sample 5 whereas minimum value of 42.54 was obtained for sample 4. The a* and b* value of cooked pasta ranged from 5.44 to 6.46 and 13.93 to 15.19, respectively. percentage elongation of the sample ranged from 21.2% to 10.3% and 20.87% to 7% in terms of length and thickness, respectively. Maximum elongation (length) was obtained for sample 2 and minimum elongation (length) for sample 3. Sample 5 had the maximum elongation in terms of thickness whereas sample 4 had the minimum elongation in terms of thickness. water activity of cooked pasta ranged from 0.892 to 0.842. optimum cooking time of the samples ranged from 5 to 8 min. Maximum cooking time was obtained for sample 1 whereas minimum value was obtained for sample 2 and sample 5.

From the quality and sensory analysis, sample 5 (20 % chickpea, 38% rice, 18% cornflour, 9 % finger millet, 9 % carrot powder and 5% guar gum) was selected the best among the other 5 samples in terms of colour, cooking characteristics and sensory qualities. Further storage studies were done for the optimized sample for 3 months. The pasta samples packed in LDPE was found safe during the storage period.

The study concluded that, the developed nutrient rich pasta incorporated with 20 % chickpea, 38% rice, 18% cornflour, 9 % finger millet, 9 % carrot powder and 5% guar gum not only ensured taste and overall acceptability, but also increased the nutrition level.

CHAPTER VI

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APPENDIX

APPENDIX I

SENSORY SCORECARD

Department of Processing and Food Engineering

KCAET, Tavanur

Name of judge: Date:

You are requested to assess the product in terms of general acceptability on a 9-point hedonic scale.

Characteristics	**Control**	**Sample A**	**Sample B**	**Sample C**	**Sample D**
Colour& appearance					
Flavour					
Texture					
Taste					
Overall acceptability					

Score System:

Dislike extremely : 1

Dislike very much : 2

Dislike moderately : 3

Dislike slightly : 4

Neither like nor dislike :5

Like slightly : 6

Like moderately : 7

Like very much : 8

Like extremely : 9

Comments if any :

Signature

APPENDIX II

Nutrient Analysis report of pasta- Storage

Sl. No.	Parameter	Result
1	Carbohydrates (g/100g)	23.0
2	Total protein (g/100g)	4.19
3	Total fat (g/100g)	0.40

ABSTRACT

Pasta by itself is a healthy nutritional diet and has great scope as an ideal functional food if supplemented with additional healthy ingredients. Taking this context into consideration there is a need to develop nutrient rich pasta that explores different health ingredients that are compatible with the physiological characteristics of pasta. A study was conducted on the development of nutrient rich pasta by cold extrusion technique using lab-scale DOLLY equipment. The samples were made by mixing ingredients of rice flour, cornflour, chickpea, finger millet, carrot powder and guar gum. The carrot was dried, powdered and mixed with pulverized cereal. The extruded pasta was dried in a cabinet dryer at a temperature of 70°C for 3hours. Based on the preliminary trials conducted, five samples were selected and its quality evaluation was conducted. L* value of cooked pasta sample ranged from 42.54 to 51.35. The maximum L* value of 51.35 was obtained for sample 5 whereas minimum value of 42.54 was obtained for sample 4. The a* and b* value of cooked pasta ranged from 5.44 to 6.46 and 13.93 to 15.19, respectively. percentage elongation of the sample ranged from 21.2% to 10.3% and 20.87% to 7% in terms of length and thickness, respectively. Maximum elongation (length) was obtained for sample 2 and minimum elongation (length) for sample 3. Sample 5 had the maximum elongation in terms of thickness whereas sample 4 had the minimum elongation in terms of thickness. water activity of cooked pasta ranged from 0.892 to 0.842. optimum cooking time of the samples ranged from 5 to 8 min. Maximum OCT was obtained for sample 1 whereas minimum value was obtained for sample 2 and sample 5. From the quality and sensory analysis, sample 5(20 % chickpea, 38% rice, 18% cornflour, 9 % finger millet, 9 % carrot powder and 5% guar gum) was selected the best among the other 5 samples in terms of colour, cooking characteristics and sensory qualities. Further storage studies were done for the optimized sample for 3 months. The pasta samples packed in LDPE was found safe during the storage period. The developed nutrient rich pasta incorporated with 20 % chickpea, 38% rice, 18% cornflour, 9 % finger millet, 9 % carrot powder and 5% guar gum not only ensured taste and overall acceptability, but also increased the nutrition level.