Impact of Hog-Plum Peel on the Bioactive and Organoleptic Properties of Wheat Noodles

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Roll No.: 0121/04

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A thesis submitted in the partial fulfillment of the requirements for the degree of Master of Science in Food Processing and Engineering

Department of Food Processing and Engineering

Faculty of Food Science & Technology

Chattogram Veterinary and Animal Sciences University

Khulshi, Chattogram-4225, Bangladesh

February, 2023

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This is to certify that we have examined the above Master's thesis and have found that is complete and satisfactory in all respects and that all revisions required by the thesis examination committee have been made

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List of Abbreviations

g/L	Gram Per Liter
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
CHO	Carbohydrate
DPPH	2,2-diphenyl-1-picrylhydrazyl
et al	Et alii/ et aliae/ et alia
GAE	Gallic Acid Equivalent
HPB	Hog Plum Bagasse
HPP	Hog Plum Peel
L	Liter
mg/dl	Milligram Per Deciliter
mmol/L	Milimol Per Liter
PPM	Parts Per Million
QE	Quercetin Equivalent
SEM	Scanning Electron Microscope
TE	Trolox Equivalent
TFC	Total Flavonoids Content
TPC	Total Phenolics Content
WF	Wheat Flour

Abstract

This study assessed the utility of Hog Plum (*Spondias pinnata*) peel with a purpose of enrichment of noodles. Although being a waste product, the peel is beneficial since it contains a lot of dietary fiber, phenols, flavonoids, and minerals (particularly iron, magnesium and potassium). It can be sorted into flour or powder after drying and combined with wheat flour (WF) to create goods with a high value-added. To assess the feasibility of creating functional noodles in this study, WF was substituted with HPP at supplemental dosages of 2.5%, 5%, and 10%. According to the statistics, there was a considerable increase in crude fiber in the composite wheat flour with 10% HPP compared to the control. Composite flour noodles were shown to have more antioxidant capacity.Total phenol content (TPC), total flavonoid content (TFC) and antioxidant capacity were 121%, 61% and 74% higher, respectively, in the side containing 10% HPP compared to the control (100% WF). However, when 10% HPP was included in WF, the swelling property decreased and the cooking loss increased by 1.40% and 1.53%, respectively. According to the sensory evaluation results, the product with 2.5% HPP added received the highest sensory profile score.

Keywords: Hog plum peel, noodles, peel extraction, bioactive substances, cooking characteristics, and waste utilization.

CHAPTER 1

INTRODUCTION

The importance of living healthy lifestyles is growing among people all over the world. Consequently, it might have an impact on both what and how people eat. The sensory characteristics of food, such as taste, texture, flavor, and appearance, are highly valued by consumers today. A consumer's choice of food may be influenced by nutritional information in addition to sensory attributes. Additionally, consumers now place a higher value on wholesome, nourishing food. The best option to meet their consumption needs is fresh fruit and processed fruit products. There have been numerous studies over the past few decades showing the value of fruit eating in reducing health risks, as well as campaigns to include fruit in children's diets (Kandylis et al., 2020).

“Functional foods are processed or natural foods that provide essential nutrients. They also have additional physiological benefits in the management, treatment and prevention of various chronic diseases” (Martirosyan, 2011). In recent times, the demand for semi-finished products with good health benefits and nutritional value has increased. In particular, foods rich in fiber (DF) have been shown to protect against certain allergic and degenerative diseases such as celiac disease, diabetes, cancer and cardiovascular disease (Ciudad-Mulero et al., 2019; Neyrinck et al..,2013; Sharma et al., 2016). Recently, the use of fruit waste such as peels, pulps, and pulps has been known to be a potential source of DF with nutritional and health benefits, and should be incorporated into baked products such as cookies (Quiles et al., 2018; Sharma et al., 2016). These advances have led various food and agricultural organizations to sustainably source dietary fiber as a functional ingredient from fruit waste that is lesser known but viable due to its unique health and nutritional benefits.

The demand for value-added grain products such as Noodle product has grown rapidly in the past few decades. Among all the foods consumed in South Asia, Noodles marking its status as “**Second**” followed by rice products (Hatcher 2001). They have been consumed for thousands of years. Noodle consumption patterns have also increased significantly among the Western population over the past decade as they have become a part of ethnic foods (Zhang & Ma 2016). Being one of the staple foods in Asia, noodles are rich in carbohydrate but lack of other essential nutritional components (Li et al.,2012). Consequently, many flours, including buckwheat, barley, coconut, sweet potato, rye, and soybean have been investigated for their ability to enrich noodles (Bilgiçli 2009; Gunathilake & Abeyrathne 2008).Composite studies have a considerably improved diet, but tied to buckwheat, sweet potatoes or coconuts, etc. It can contribute to costs (Izydorczyk et al. 2005). According to a report by Market Research Future (MRFR), the global market for instant noodles will be worth USD 81.90 billion by 2030 at a 6% CAGR.

According to the Bangladesh Bureau of Statistics, more than 42,500 tonnes of hog plum were produced in Bangladesh in fiscal 2020–21 on roughly 11,400 acres of land, an increase of about 5% over the previous two years. Hog plums are a minor fruit; primarily eaten fresh, though they can also be used commercially and on a small scale to make jam, jelly, squash, and marmalades. When the edible parts of the fruit are consumed or used, a lot of the hog plum peel is left untouched.

According to FAO (2016), fruits and vegetables have the highest rates of food waste, with 1.6 billion tonnes wasted annually. "The food processing industry and pollution monitoring organizations view these wastages as a problem" (Chacko, C. M., & Estherlydia, D., 2014). Even though this peel can be fed to livestock or even used as fertilizer, some farmers still view it as waste. However, all these waste materials could be a potential source of worthwhile by-products like essential oils (EOs), which can be extracted from fruit rinds. Fruit peel and wheat flour in instant noodles results in a more affordable, nutrient-dense product with a longer shelf life. For similar food types, such as noodles, there are many natural sources of additives such as lupine and pigeon pea flour (Martínez-Villaluenga, Torres, Frías, & Vidal-Valverde, 2010), protein cereal (Gallegos -Infante et al., 2010), mango peel powder (Ajila, Aalami, Leelavathi, & Prasada Rao, 2010), marigold anthocyanin beet pigment (Zhu, Cai, & Corke, 2010), banana powder, and β- glucan (Choo and Aziz, 2010) trialed to improve the nutritional value and functional properties of the product.

Besides, the phytochemicals found in hog plum peels are extremely helpful in battling a number of health issues, including a decrease in lipid oxidation and lower cholesterol, as well as a reduction in chronic illnesses most importantly cardiac disease, obesity, and cancer, which are common in the western world.

Hog plums are an import-focused fruit that is increasingly popular in Bangladesh as a healthy fruit or juice. The peels, which contain almost 30% of the fresh fruit after consumption and manufacturing, are thrown away as waste. This hog-plum peel is the starting point for our procedure. The aim of this study was to formulate hog plum peel fortified noodles using hog plum peel powder & peel extract. Using a variety of instruments, the polyphenol in the hog plum peel can be extracted and used to make noodles. This is a more efficient way to use the hog plum peel. Hence, this experiment outlines the following objectives:

1. To examine the bioactive characteristics of peel extract obtained from hog plum.
2. To prepare fortified noodles and compare it with regular wheat noodles.
3. To determine proximate analysis and mineral composition between wheat noodles and peel enriched noodles.

CHAPTER 2
REVIEW OF LITERATURE

If the study's conceptual framework is based on the ideas and thoughts gathered from survey work of existing writing in both hypothetical and observational form, it will be simpler to organize the research in a thorough manner.

2.1 Hog Plum

Hog plum (*Spondias pinnata*) is an edible wild fruit belonging to the Anacardiaceae family and widespread in India, Sri Lanka, Bangladesh, China and other Southeast Asian countries. It is naturalized in parts of Africa, India, Nepal, Bangladesh, Sri Lanka, the Bahamas, Indonesia and other Caribbean islands. The ripe fruit has a leathery skin and a thin layer of pulp. The pulp is eaten fresh or made into juices, concentrates, jellies and sorbets.

In the Caribbean and Asia, where the fruits naturally grow, hog plums are frequently consumed raw. Hog plums are related to mangos and have a sweet-sour taste, depending on ripeness. The fruits can be consumed whole and in raw form as a snack, as well as being frequently made into fresh juices, ice cream, jams, and jellies. In Mexico, unripe hog plums are pickled to create a sour-spicy side dish (Faijul & Hayder,2016). In Bangladesh, where the fruit is called “Amra”, it is typically served with chili powder. It is known as ‘Omora’ in Assamese and ‘Amado’ in Konkani in India. This fruit is known as ‘Lapsi’ in Nepal. However, in Sanskrit, "Amra" is translated as “Mango”.

The fruit is used as an astringent, a refrigerant, and a treatment for muscular and articular pain (Kritikar & Basu,1975). It is rich in vitamin C and functions as a natural cure for scurvy, influenza, and other viral infections. Due to the iron it contains, it can also lessen anemia (Faijul and Hayder 2016). Because hog plums are a seasonal fruit, they are only occasionally available in fresh form.

Figure 2.1: Hog Plum (Amra) Fruit

Taxonomical classification

Kingdom: Plantae

Divison: Tracheophyta

Class: Magnoliopsida

Superorder : Rosanae

Order: Sapindales

Family: Anacardiaceae

Genus: Spondias L. – mombin

Species: Spondias pinnata (L. f.) Kurz

The fruit is simple, 1.5-2.5 cm long and 0.7-1.13 cm in diameter, round, juicy and a type of single-seeded drupe, fleshy with a delicately flavored pulp and without hazard for consumption (Figure 2.1). The epicarp is thin, greenish yellow when ripe. The mesocarp is slightly acidic, juicy when ripe, aromatic, 6-8 cells, the inner part of the endocarp is hard, woody and furrowed, the outer part is fibrous. Unripe fruits are extremely sour, while ripe ones have a spicy note with a pleasant aroma. The seeds bear ridges, semi-lignified, fibrous and pitted on the outside (Sumanta, et al., 2021).

Only a small amount of work has done with hog plum peel; which is used for the extraction of essential oils. The hydro-distilled hog plum peel essential oil can be used to improve food products' flavor and taste as well as to cover up the unpleasant smell of drugs. As a result, *Spondias mombin* waste peels seem to be valuable economically (Plabon, M. E. A. ,et al. ,2021).

2.2 Chief Utility of Hog Plum

The climacteric fruit, Hog Plum exhibits enhanced climacteric respiration on the fourth day of storage, reaching a maximum after 7 days, with the senescence process begins on the eighth day of storage, resulting in around 50% postharvest losses when not handled promptly (Sampaio, S. A., Bora, et al. 2007). Due to value addition, the fruit's restricted commercialization due to its short shelf life may alter.

Several studies have demonstrated the nutritional value of the fruit pulp, leaves, and bark of the *S. mombin* tree, but there is little information on the peel and pulp during the stages of ripening. Therefore, it is crucial to comprehend how ripening affects the physicochemical makeup of the pulp and peel because it may have an impact on the process of value addition.

Since a valuable source of vitamin C; the ripe fruits are consumed as pickles, chutneys, jams, and sherbet. They are also consumed for their sour and slightly bitter taste. According to Morton (1987), fresh fruit, pulp, juice, ice cream jellies, pickles, relish, soups, stews, and juices are all common uses for Spondias fruit. They can also be used as flavoring (Graham et al., 2004), food additives (Koubala et al., 2008), pharmaceuticals, environmental problems, industrial relevance, gum exudates (Pinto et al., 2000 and Pinto et al., 1996), and fructification of mushrooms (Ramsundar et al., 2002).

Despite the fact that there have been very few hog plum-related activities in our country, several works have been produced there. As part of their research, S. Akther and colleagues developed leather, jelly, and sensory evaluation techniques for fresh Mymensingh and Barishal hog-plums (Spondius mangifera). The purpose of that paper was to investigate the chemical makeup of new Mymensingh and Barishal hog plums as well as the production of leather. The chemical composition of fresh hog plums from Mymensingh and Barishal, as well as dehydrated products, are compared. leather. In that paper, hog-plum processing and preservation were carried out using equipment that was readily available locally, utilizing low-level technology with little initial outlay of capital.

M.H.R. Bhuiyan tried to develop pickles and chutney from fresh hog plum (*Spondias dulcis*). The study was carried out with the goals of identifying the ideal recipe for hog-plum pickle and chutney, as well as to study the storage-life of the prepared hog-plum pickle and chutney. 5 %, 10%, 15%, and 20% salt concentrations were used to make the pickle. The chutneys were formulated with a 25%, 30%, 35%, and 40% sugar concentration.

In many traditional herbal medicines around the world, the hog plum plant has been heavily utilized. Hog plum fruit leaves and pulp extracts have anti-tumor and antibacterial properties (Murakamia et al. 1995; Mahanta et al. 2006). Due to the significant amount of phenolic content it contains, this wild fruit exhibits significant qualities. It has been shown to have biological effects on ovarian cancer cells, protect against gastroenteritis in rats, and be an antioxidant.

Because of the fruit pulp's flavor, which can range from sour to sour-sweet, high mineral content, vitamin A and C content, potassium content, reducing sugar content, copper content, intense antioxidant activity, and higher total phenolic compounds (TPC) content than other fruits, consumption of fruit pulp as a raw or processed food has increased (Tiburski, J.H., Rosenthal, et al., 2011). Hog plum fruit extracts are used to treat joint and muscle pain since they have been demonstrated in multiple studies to have diuretic, antipyretic, antibacterial, and anticancer activities as well as neuroprotective qualities. These characteristics are probably due to the high concentration of phenols and antioxidants, phytonutrients, phytosterols, minerals, carotenoids, and terpenoids in hog plum pulp (Sameh, Salma et al. 2018).

Bioactives, like the polyphenols found in *spondias mombin*, may have beneficial properties like anti-cancer, anti-inflammatory, and antioxidant properties. The consumption of these substances has been shown in studies to reduce oxidative stress and chronic diseases (Brito, G. O. D., B, and Reis. C., et al., 2022).

On the other hand, research indicates that increasing the intake of foods high in antioxidants, such as polyphenols, lowers the risk of developing chronic diseases. A substrate that can be oxidized in a chain reaction can either be delayed by antioxidants or have its oxidation inhibited. Additionally, natural antioxidants like polyphenols are being used more frequently in the food and pharmaceutical industries. Due to their potent antioxidant properties both in vitro and in vivo as well as their ability to scavenge free radicals, which are responsible for the body's destructive oxidation response, phenolic compounds have attracted the attention of researchers in particular. Free radicals' oxidative damage to nucleic acids, proteins, and lipids accelerates aging and causes a number of degenerative diseases, including. diseases like diabetes, cancer, and cardiovascular conditions. as well as other human chain reactions (Zhang et al. 2019; Maxwell 1997). Fruits and vegetables high in antioxidants scavenge free radicals created by stress and pollution, lowering the risk of these diseases (Gupta et al. Sarin et al., 2013, Page 3/21., 2012). Since synthetic antioxidants like BHA and BHT are carcinogenic, natural sources are preferred in both food and medicine (Velioglu, et al., 1998). It brings to mind the proverb attributed to Hippocrates, “Let food be thy medicine and medicine be thy food.” Fruits and vegetables have phenolics, flavonoids, and pigments, which are thought to have nutraceutical properties. As a result, another objective of our research is to assess the antioxidant activity of hog plum peel powder.

The hog-plum's peels, which make up about 30% of the fruit, are rich in various nutrients. Hog Plum's peel also has a notable concentration of total polyphenols (Brito, G. O. 2019). The peel is typically discarded, squandering its potential for use and economic gain. It can be considered industrial waste. In a study that evaluated the bioactives in acerola (Malpighia emarginata L.), industrial waste, umbu (Spondias tuberosa L.), genipap (Genipa americana L.), and guava (Psidium guajava L.), as well as their high phenolic content, Gualberto et al. and other studies (2021) supported this potential in a few exotic fruits. Studies on waste, especially peel, can therefore aid in the development of goods with value-added components like edible films, probiotics, and nanoparticles, among others (Kumar, H. Keshav Bhardwaj., Sharma, R., and others. 2020). Industrial byproducts can be used to reduce waste and generate profitable outcomes for both society and the environment (DeHond et al., 2018).

2.3 Polyphenols

Polyphenols are a class of compounds found in many plant foods, including flavonoids, phenolic acids, lignans, and stilbenes. To date, more than 8,000 different types of polyphenols have been identified. Some polyphenols that have gained popularity are epigallocatechin gallate (EGCG) in green tea and resveratrol in grapes and wine.

A phenyl ring is joined to one or more hydroxyl groups to form polyphenols, which are essentially natural chemical molecules. In the defense system of plants against numerous microorganisms (fungi, viruses, and bacteria) as well as herbivores, polyphenols play a critical role. According to Cui et al. (2012), Güllüce et al. (2003), and Papuc et al. (2017), they are biosynthesized from tyrosine/phenylalanine.

According to scientific evidence, several illnesses and disorders are either directly or indirectly caused by oxidative damage (Cutler, 2005). Natural anti-oxidants called polyphenols are crucial in the prevention of oxidative stress and protect against a variety of diseases that are linked to it (Safdar et al., 2017; Santhakumar et al., 2014). In addition to their antioxidant activity, polyphenols have a number of additional health advantages. Certain cancers, cardiovascular diseases, diabetes, and neurodegenerative diseases may be prevented by eating a diet high in polyphenols, according to some studies.

The phytochemicals known as bioactive compounds help protect human health from chronic degenerative diseases. According to Dragovic-Uzelac, Verica, et al. (2007), polyphenols are a class of biologically active substances found in plant-based foods. These substances come from plants, such as fruits, vegetables, cereals, and coffee, and are an integral part of the human diet.

The polyphenols and bioactive substances present in tea, red wine, cocoa, fruits, fruit juices, and olive oil have been shown to have a cellular impact on carcinogenesis and tumor development (Lee, J. Surh, Y. and Sdot. J. 2005). The primary agents responsible for such marvels include various substances like carotenoids, phytochemicals, flavonoids, and polyphenols (Boyer and Liu, 2004).

Fruit coverings are rich in flavonols, as their production is activated by light. Flavonol levels vary in fruits on the same plant, and even on the same fruit, due to light exposure at their different edges (Archivio, Massimo, et al. 2007).

Classification of Polyphenols

Polyphenols are mostly of plant origin and are among the most studied classes of phytochemicals. Polyphenols can be easily classified into flavonoids and non-flavonoids, or divided into many subclasses, depending on the number of phenolic units within their molecular structure, the substituent groups and/or the type of bond between the phenolic units. Polyphenols are classified according to the number of phenolic rings they contain and the structural elements that bind these rings together. They are roughly divided into four classes;

a. Phenolic acids
b. Flavonoids
c. Stilbenes and
d. Lignans

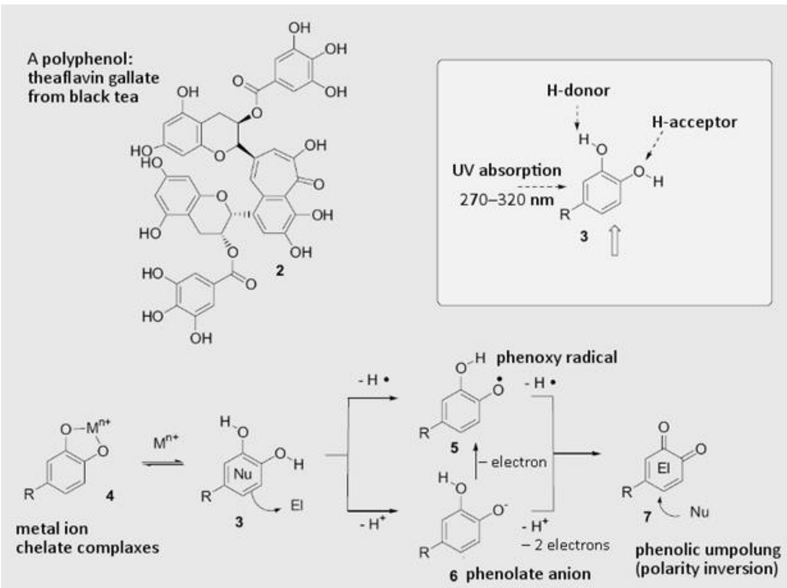

Figure 2.2. Phenols: Structures and Reactivity (Journal: Chemistry Views)

Sources of Polyphenols

Generally speaking, fruit waste contains more polyphenols than fruit pulp, especially in the fruit peel. Fruit peels have a higher potential for antioxidants than fruit pulp, according to studies. According to Jabbar et al., the amount of various phenolic compounds in fruit peels is significantly higher than that in the pulp, including carotenoids, anthocyanins, flavonoids, and phenolic acids (Jabbar et al., 2015; Safdar et al., 2017). Pomegranate peel is a significant agricultural waste but is also high in polyphenols, or hydrolysable ellagitannins, making it a great natural source of antioxidants (Kushwaha et al., 2015).

Akinlolu-Ojo, T., et al.(2022) reported in a study that, via UPLC-MS/MS, different phenolic compounds were quantified, such as flavonols, phenylpropanoids, benzoic acid derivatives, coumarins, stilbenes , dihydrochalcones, flavones and flavonones in hog plum peel (spondias mombin). Of the flavonols, 14 compounds were quantified. Quercetin was the most abundant compound, followed by myricetin and Kaempferol-3-Glc.

Extraction Methods of Polyphenols:

For the extraction of polyphenols, polar organic solvents such ethyl acetate, ethanol, methanol, and acetone are typically utilized (Ross et al., 2009). Maceration, a common solid-liquid extraction method, was one of the methods used in the current investigation among the different methods used for the extraction of polyphenols (Garcia-Salas et al., 2010). As a different method, sonication has the drawback of having lower experimental repeatability (S. Ramos, J. Nutr. Biochem. 2007).

Several extraction methods have been reported for the extraction of polyphenols; these include microwave extraction, ultrasonic extraction, Soxhlet extraction, heat reflux extraction and ultra-high-pressure extraction. Hydrophilic polyphenols including aglycones, glycosides and oligomers are extracted using water, polar organic solvents such as methanol, ethanol, acetonitrile and acetone or their water mixture. Liquid extracts are sometimes partitioned with solvents such as ethyl acetate, depending on the solubility of the target polyphenols. Polyphenols are more stable at low pH because the acidic state allows polyphenols to remain neutral and therefore easily extracted in organic solvents.

I. Conventional Extraction

The water bath is an indirect heating method that has been used for decades. The plant material is slowly heated to allow maximum extraction. As the temperature rises, the plant tissue begins to release its internal contents into the medium. A longer extraction time gives better results. Conventional extraction and concentration of polyphenols using a water bath is usually carried out at temperatures between 20 and 50°C, temperatures above 70°C cause rapid degradation of polyphenols. Increasing the temperature increases the efficiency of the extraction, since the heat permeates the cell walls, increases the solubility and diffusion coefficients of the compounds to be extracted and reduces the viscosity of the solvent, facilitating its passage through the mass of solid substrate. However, the use of temperatures above 50°C reduces the overall yield of polyphenols and pro-antho-cyanidins, probably due to their degradation.

II. Microwave-Assisted Extraction (MAE)

The use of MAE in the extraction of natural products began in the late 1980s and thanks to technological developments, it has become one of the most popular and cost-effective methods of extraction, with several instruments and advanced MAE methods now available, e.g. pressurized microwave-assisted extraction (PMAE) and solvent-free microwave-assisted extraction (SFMAE). This method allows multiple quantitative sample extractions in minutes with improved reproducibility and reduced solvent consumption. High temperature and temperature control can also be achieved using this method.

III. Solvent Extraction

Solvent extraction is commonly used to extract phenolic compounds from their plant sources due to their ease of use, efficiency, and broad applicability. Chemical extraction depends on the type of solvent, the polarity of the solvent, the extraction time and temperature, as well as the chemical composition and physical characteristics of the samples.

IV. Ultrasound-Assisted Extraction (UAE)

Ultrasonic extraction depends on the destructive action of ultrasonic waves. UAE is useful for intensifying mass transfer, cell disruption, enhanced penetration and capillary effects. The very high temperatures in the UAE increase solubility, diffusivity and pressure which help the waves to penetrate tissues and transport contents into a variety of organic and inorganic solvents. The ultrasonic probe and the bath are the two most commonly used systems for extraction. VAEs have the disadvantage of reduced experimental reproducibility.

2.4 Noodles

Noodles are a type of unleavened dough food that is rolled and cut, stretched, or extruded into long strips or strings. Noodles are a staple in many cultures (for example, Chinese noodles, Filipino noodles, Indonesian noodles, Japanese noodles, Korean noodles, Vietnamese noodles, and long and medium Italian pasta) and are made in a variety of shapes. Wheat-based noodles became an important food for the people of the Han Dynasty (Sinclair & Sinclair 2010). The oldest evidence of noodles dates back to 4,000 years ago in China (Roach, John 2005). While long, thin strips are perhaps the most common, many types of pasta are cut into waves, spirals, tubes, strings, or shells, or folded or cut into other shapes. The noodles are usually cooked in boiling water, sometimes with the addition of cooking oil or salt. They are often fried or fried. Noodles are often served with a side sauce or in a soup. Noodles can be refrigerated for short term storage or dried and stored for later use.

Regular wheat noodles can be made at home with minimal specialized equipment and are perfect for the novice baker. Noodles contain a lot of carbohydrates (about 73%) and are therefore mainly a source of calories. There are 219 calories in 1 cup of cooked noodles (Source: FatSecret Platform API). Hence, it should be consumed in moderation by those looking to lose weight.

However, instant noodles are now being promoted as a nutritional vehicle in developing countries by fortifying either the flour used to make the noodles or the spice powders eaten with the noodles (Winichagoon, Pattanee, et al. 2006). Therefore, this study is aimed to develop fortified noodles by checking the contribution of hog plum peels.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

Our experiment was accomplished in the laboratory of the Department of Food Processing and Engineering, Department of Physiology Biochemistry and Pharmacology and Department of Animal Science and Nutrition of Chattogram Veterinary and Animal Sciences University (CVASU), Khulshi, Chattogram-4225.

Figure 3.1: Sample Collection and Study

3.2 Study Duration

The study was conducted over a four-month period, from September to December 2022

3.3 Collection of Sample

Fully fresh fruit was purchased early in the morning from local fruit market (New Market) at Chattogram, and delivered to the Department of Food Science and Technology at Chattogram Veterinary and Animal Science University (CVASU) in Chattogram. Bangladesh. Solvents and reagents used in the study were analytical grade from Merck, Germany, supplied by the distributor Transcom. The fruit has been washed to remove any dust, dirt or residues of any kind of pesticides, herbicides, fungicides, etc.

3.4 Preparation of Hog Plum Peel Powder

Fruit peels were chopped into little pieces after being separated from the fruit juice. The peels were collected, then immersed for two minutes in a KMS (Potassium Metabisulfite E 222) solution to maintain their natural color, avoid blackening, and provide bacterial protection. The peels were subsequently dried using a "Cabinet Dryer" for 48 hours at 60°C to a consistent weight. The dried peels, which had a moisture content of less than 10%, were ground into a fine powder with the use of a "Mixer Grinder" (Panasonic MX-AC300). The peel powder was then placed in sealed plastic zip bags after being filled. The bags were then stored at a cold (4-6°C) temperature.

3.5 Proximate Analysis of Peel Powder

Hog Plum peel powder was analyzed for moisture, ash, crude protein, crude protein, crude fat, and crude fiber according to the standard methods of the Association of Official Analytical Chemists. Available carbohydrate in peel powder was estimated. Proximate Analysis were established for fruit peels along with Noodles samples.

3.6 Extraction of Polyphenols

Conventional Extraction (Maceration) procedure was used for polyphenol extraction from hog plum peel powders

Extraction (Maceration):

The maceration method of Elfalleh et al. (2012) was used to extract polyphenols from hog plum peel powder which to be slightly modified. Preliminary studies were followed to determine optimal solvent concentrations (25%, 50%, 75%, and 100%) and sample/solvent ratios (1:20, 1:15, and 1:10). Three different solvents were used including acetone, methanol and ethanol at concentrations selected after preliminary studies. 50% and 75%. The sample/solvent ratio was set to 1:6 and the temperature of the maceration method was set to 60 °C. Briefly, 50 g of the peel was placed in a conical flask and 300 ml of solvent was added using a "Hot Stirrer" magnetic stirrer (Labtech LMS-1003, DAIHAN LABTECH CO., LTD, Indonesia). The conical flask was placed on a heated stirrer for about 2 hours. Later 2 hours, all samples were strained with Whatman 41 filter paper and centrifuged at 5000 rpm for about 10 minutes (Beckman J2-21, Brea, CA). The solvent was then evaporated using a rotary evaporator (Rotavapor R-300, Switzerland). Solvents were evaporated in vacuum at 200 mbar and a temperature of 65 °C until dry, and extracts were collected using small plastic vials and stored in a refrigerator at 4–6 °C.

3.7 Bioactive Properties Analysis of Ethanolic Extract

The total polyphenol content (TPC) from peel extract was evaluated by the Folin Ciocalteau method described by Al-Owaisi et al., (2014). The TFC of hog plum peel ethanol extract was evaluated by Chang et al. (2002) with minor modifications. In addition, the antioxidant activity of cherry plum peel extract was evaluated by Azlim et al. (2010) with minor modifications.

3.8 Formulation and Preparation of Flour Blends

A modified approach described by Pasha et al.(2022) was used for this process. A nearby grocery (Monohari Bitan, New market; Chattogram) sold wheat and other components for producing noodles. The blends were combined using a home food mixer (Panasonic MX-AC 300) for 5 minutes to create composite flours with wheat and fruit peel at inclusion levels of **2.5, 5 and 10%.**

3.9 Design of Experiment

The product was prepared with hog plum peel powder and peel extract. The different percentage of fruit peel powder and peel extract were used for preparation of Noodles. The treatment combinations are presented in Table 3.1

Number of Treatment: 03

Table 3.1: Treatment of Experiment

Treatment	Treatment Combination
T1 (Control)	Wheat noodles with No Polyphenol & peel powder
T2 (Sample A)	Flour (72.5%) + Peel Powder (2.4%) & Extracted Polyphenol (0.1%) + Other ingredients (25%)
T3 (Sample B)	Flour (70%) + Peel Powder (4.8%) & Extracted Polyphenol (0.2%) + Other ingredients (25%)
T4 (Sample C)	Flour (65%) + Peel Powder (9.6%) & Extracted Polyphenol (0.4%) + Other ingredients (25%)

3.10 Development of Noodles

Wheat flour in the experimental formulation was replaced with total of 2.5, 5 and 10% hog plum peel powder along with mentioned proportions of polyphenol ethanol extract. Wheat flour was mixed with wheat (5g/100g flour), baking powder (1g/100g flour), table salt (2g/100g flour) and drinking water (35ml/100g total weight). The dough was stretched and covered with a neat wet cloth, rested for 30 minutes, kneaded by hand for 1 minute, and stretched in a hand-operated noodle maker. After that, the dough plate was passed through a manual noodle making machine. The resulting strand was cut to about 20 cm and folded into the desired shape. As a control sample, plum skin and cotton without polyphenol were used. Strands of noodles were then steamed at 100 °C for 2 min, then cooled to 25 °C and dried in an oven overnight. The product was then cooled to room temperature and stored in Ziploc plastic bags until further analysis.

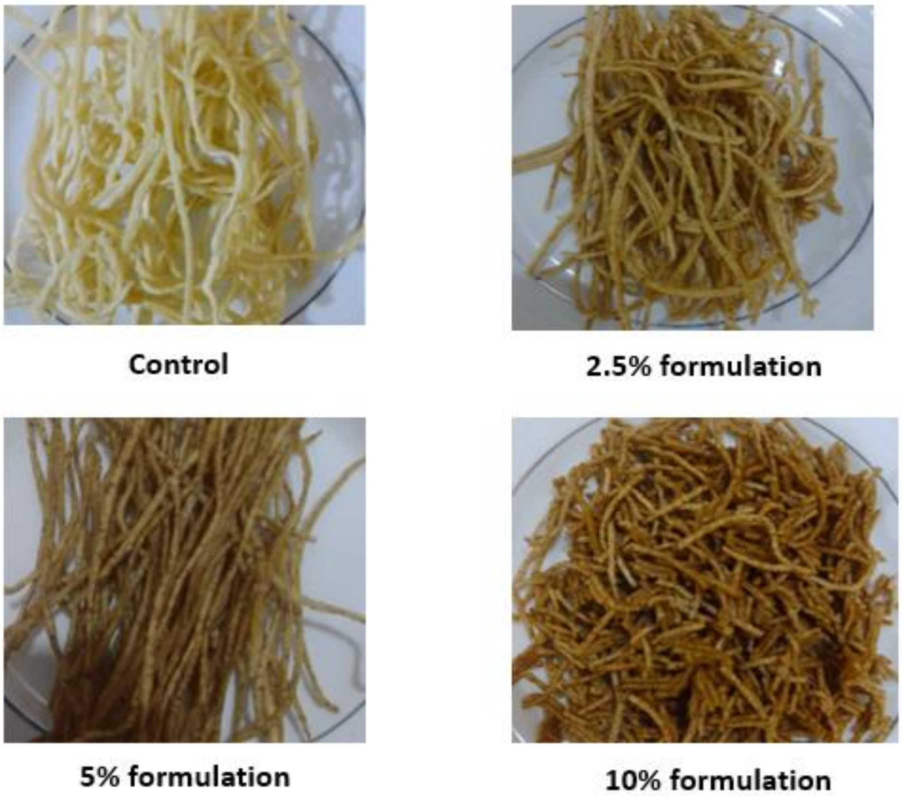

Figure 3.2: Noodles Samples

Flowchart for Preparation of Noodles Using Fruit Peel:

Selection of raw materials

⇩

Mixing of ingredients

⇩

Dough resting for 30 min

⇩

Rolling

⇩

Extrusion by Noodles machine

⇩

Steaming

⇓

Drying at 60℃

⇓

Noodles

⇓

Packaging

Figure 3.3: Flowsheet for Incorporated Noodles

(Ref: Pakhare, K. N., et al., 2016)

3.11 Chemical Composition Analysis of Peel Fortified Noodles

Estimation of Moisture:

One of the simplest and most often tests used in the food industry is moisture determination. The moisture content of foods has direct economic significance for both the processor and the consumer, as dry matter is inversely proportional to moisture. However, the impact of humidity on the shelf life and quality of meals is even more important. The method of the Association of Official Analytical Chemists (AOAC, 2016) was used to calculate the percentage of total moisture.

Estimation of Ash:

Ash content was estimated using AOAC (2016) protocols. Ash is an inorganic by-product of the decomposition of organic matter. A pre-weighed tray was used to measure 10 g of dried noodles. Then it was turned into charcoal by combustion. Next, a muffle furnace was used to heat the charcoal to a temperature of approximately 600°C for 4 hours, at that time with the complete removal of charcoal. Then the lab-crucible was removed from the furnace. It was kept in a desiccator and allowed to cool for some time before being weighed.

Estimation of Crude Fiber:

The water-insoluble carbohydrate portion of crude fiber includes cellulose, hemicellulose and lignin macromolecules. To do this, the known amount of fat-free food is boiled in a dilute acidic solution (1.25% H_2SO_4) for 30 minutes, then boiled in a dilute alkaline solution (1.25% NaOH) for 30 minutes, maintaining a constant volume, and the ashes are then subtracted from the resulting residue to obtain an estimate. In this study, the AOAC (2016) technique was used to calculate the crude fiber content. The ashes were created by burning the waste in a muffle furnace at (550-600)°C for 4-6 hours.

Estimation of Fat:

To assess the fat substance, these nourishment tests are broken up in natural solvents (chloroform: methanol) and the filtrate is at that point sifted. The filtrate is at that point isolated utilizing the separatory pipe, the blend is at that point dried for the estimation of the extricate and the fat substance is decided. The unrefined fat substance of the tests was calculated utilizing the AOAC (2016) strategies designed for the Soxhlet device. A Soxhlet device was utilized to calculate the full sum of unrefined fat. The dried and weighed test was put away in a fixed thimble with grease-free cotton. The thimble was utilized to put the fat extraction tube into the Soxhlet flask. The flask was charged with 75 ml of dry ether and the best of the fat extraction tube was joined to the condenser. The fundamental substance was recovered inside a greatest period of 16 hours. When the division handle was total, the thimble was expelled and the Soxhlet tube was utilized to distill and collect the ether. By the time all the ether had been poured out, the tube would have been about full. After the volume of ether containing the test fat granules was decreased to an greatly low esteem, the ether was exchanged through a pipe into a container. Ether was utilized to wash and filter the jar. The ether was at that point dissipated in a steam shower kept at a low temperature.

Estimation of Crude Protein:

The Kjeldahl method is used to determine how much nitrogen is present in both organic and inorganic samples. The Kjeldahl nitrogen content is calculated to determine the amount of protein present in foods and beverages, as well as in meat, feeds, cereals, and forages. In order to determine how much nitrogen is present in wastewaters, soils, and various other materials, the Kjeldahl method is also used. It is a recognized technique, and several normative sources, such as (AOAC, 2016), provide descriptions of it.

Calculating the nitrogen or protein content requires taking into account the type of receiving solution and any dilution factors applied during the distillation process. Boric acid is a popular option for the receiving solution.

Estimation of Carbohydrate:

Carbohydrate content was calculated by determining the nitrogen-free extract value (NFE) value. It was generally calculated as the difference between 100 and the summation of the other proximate components.

3.12 Determination of Mineral Content of Formulated Noodles:

According to AOAC (2010), this technique uses digestion to draw the minerals from the food source. Noodles were dissolved in a 2:1 HNO_3/$HClO_4$ acid solution and then digested. One gram of sample was weighed and placed in a conical flask. A conical flask was filled with one gram of sample, which had been weighed. The conical flask was placed on a hot plate set to 200W for 3 minutes after adding 7 ml of HNO_3 and 3 ml of $HClO_4$ to ensure complete digestion. The prepared solution was allowed to cool before being filtered into a 100 ml standard flask using filter paper. Distilled water was then used to dilute the prepared solution to volume. This solution was subjected to the AAS method of mineral content analysis. (German origin, Humalyzer-3000).

Determination of Potassium:

When potassium and sodium tetra-phenyl-boron are combined, potassium tetra-phenyl-boron is produced as a fine turbidity. The amount of potassium concentration in sample has an inverse relationship with turbidity. 1 ml of potassium reagent and 0.02 ml of deionized water were pipetted into a cuvette to create the blank solution. A cuvette held 1 ml of sample extract, 0.02 ml of potassium standard, and 1 ml of potassium reagent to make up the sample solution. These were combined, followed by a 5-minute retention time incubation. Within 15 minutes, absorbance was measured in comparison to both a blank and the Standard. By dividing the ratio of sample absorbance to standard absorbance by the reference concentration (mmol/L), the amount of potassium was calculated in millimoles per liter (mmol/L)

Determination of Calcium:

O-cresolphthalein and calcium ions mix to generate a violet chemical in an alkaline environment. 1 mL of the working reagent was combined with 25 L of distilled water to make a reagent blank solution, which was then placed in a cuvette. The standard was adjusted by mixing 25 L of the calcium standard with 1 ml of the working reagent. The sample solution was made up of 1 ml of the working reagent and 25 L of the sample extract. The absorbance of the sample and the reference were measured. The standard concentration (mg/dL) was multiplied by the ratio of sample absorbance to standard absorbance to determine the calcium concentration in milligrams per deciliter.

Determination of Magnesium:

Magnesium and the metallochrome indicator calmagite bind specifically in an alkaline pH. The method is built around this shift in absorption wavelength. It has been discovered that the strength of the resulting chromophores is proportional to the amount of magnesium present in the sample. In order to create the reagent blank solution, 1 mL of the reagent was added to the cuvette. A cuvette with 1 mL of reagent was filled with the sample solution, which required 10 L to prepare. In the cuvette, the standard solution was made by mixing 1 ml of reagent with 10 ml of magnesium standard. The cuvettes were left at room temperature for two minutes following the mixture. Each standard sample's 520 nm absorption was compared to that of the reagent's blind control. By multiplying the sample's absorption value by the reference concentration, the magnesium concentration was calculated in milligrams per deciliter.

Determination of Iron:

The iron is released from the transferring complex when it is dissolved in a slightly acidic solution. To change the free iron to its bivalent state, ascorbic acid is used. When ferrozine and iron ions are united, a bright molecule is created. The amount of iron in the sample affects how intense the resulting hue of molecule is. 1 ml of reagent was pipette-deposited into a cuvette to form a blank solution. The standard contained 200 L of standard and 1 ml of reagent. The sample solution was made by mixing 200 L of the sample extract with 1 mL of the reagent. After mixing, the mixture was incubated at room temperature for 10 minutes. Absorbance was determined by comparing a standard and a sample to a blank. The iron concentration was calculated in micrograms per deciliter.

Determination of Zinc:

A purple color complex is created when Nitro-PAPS and zinc react in an alkaline medium. The amount of zinc present in the sample has a direct correlation with the intensity of the complex that results. 1 mL of the reagent was put in the cuvette to make the reagent blank solution. In a cuvette containing 1 mL of reagent, the sample solution—which required 10 L to prepare—was added. 1 mL of reagent was added to 10 mL of zinc standard in the cuvette to create the standard solution. The cuvettes were combined and then kept at room temperature for two minutes. Each sample's and standard's 570 nm absorbance was contrasted with the reagent blank. By multiplying the absorbance value of the sample by the standard concentration, the zinc concentration was calculated as milligrams per deciliter in parts per million (ppm).

Determination of Phosphorus:

An antimony-phospho-molybdate complex is produced when ammonium molybdate, antimony potassium tartrate, and diluted phosphorus solutions react in an acidic medium. Ascorbic acid reduces this complex into a vibrantly blue one. The color and phosphorus level are proportionally related. At predetermined intervals, the system tracks the change in absorbance at 365 nm. The amount of phosphorus present in the sample is directly proportional to this change in absorbance. The amount of phosphorus was determined in millimole per liter.

3.13 Determination of Antioxidant capacity by DPPH scavenging method

Extract preparation

A one-gram sample was placed inside the Felcon tube. 10 mL of Absolute methanol was added after that, and the mixture was let to sit for 72 hours. Continuous straining was done every 4 hours. The filtrate was gathered after 72 hours, and methanoic extract was made.

Procedure

Using a slightly modified version of the described method (Azlim et al., 2010), we measured the antioxidant mobility of the extracts using the DPPH test. A methane solution of DPPH was obtained by dissolving 6 mg of DPPH in 100 ml of 100% methanol. To prepare a methane solution of DPPH, 6 mg of DPPH was dissolved in 100 ml of 100% methanol. The methane extract was diluted with 2 ml of DPPH solution. After gentle shaking, the mixture was placed in the dark at room temperature for 30 minutes. A UV-VIS spectrophotometer (UV-2600, Shimadzu Corporation, Japan) was used to measure the absorbance at 517 nm. Controls were performed by mixing 1 ml of methanol and 2 ml of DPPH solution, with methanol used as a blank. Scavenging mobility was determined by comparing the absorbance of the sample to that of the DPPH reference solution. Trolox was used as standard and TEAC composite was used as calibration curve (Trolox antioxidant equivalent mobility). Results are expressed as milligrams (mg) per 100 grams of powder on a dry weight basis (DW).

3.14 Determination of Bioactive Compounds:

Preparation of extract:

Felcon tubes containing 1 gram of sample were used for TPC and TFC. Then 10 ml absolute ethanol was added and the mixture was left for 72 hours. The filtering process was repeated every 4 hours. After 72 hours, alcohol extract was found in the collected filtrate.

Total Phenolic Content (TPC):

The total phenolic content of the extract was calculated using a modified version of the Folin-Ciocalteu reagent method (Al-Owaisi et al., 2014). The modified Folin-Ciocalteu method was used to determine the noodles' total polyphenol content (TPC). A Falcon tube containing 1 ml of ethanol extract was mixed with 1.5 ml of FC reagent and incubated for 3 minutes at room temperature. After waiting another 60 minutes, 1.5 ml of Na_2CO_3 (7.5%) was added to the mixture. Absorbance at 760 nm was measured using a UV-VIS spectrophotometer (UV2600, Shimadzu Corporation, Japan) using ethanol as a control. The total phenol content of the sample was calculated from the gallic acid standard curve and expressed as (mg GAE/100 g).

Total Flavonoid Content (TFC):

The total flavonoid content (TFC) of the samples was determined by Chang et al. (2002). An aliquot of 0.5 ml of the diluted extract was diluted with 1.5 ml of 95% ethanol in a cuvette of extract stock solution (1 mg/ml). A total of 2.8 ml of distilled water, 0.1 ml of 10% $AlCl_3$ and 0.1 ml of 1 mol/l potassium acetate were added to the cuvette mixture. After 30 minutes at room temperature, the mixture is ready to use. A UV-visible spectrophotometer was used to detect absorbance at 415 nm (UV2600, Shimadzu Corporation, Japan) using a control solution composed of equal amounts of distilled water and 10% aluminum chloride. Total flavonoid content was calculated and expressed as (mg QE/100 g).

3.15 Cooking Qualities of Developed Noodles

Volume of dried raw noodles (ml)

The volume of dried raw noodles was measured by the sand displacement method. A known amount (25 g) of noodles was weighed and loaded into a measuring cylinder. Take a known amount of water (100 ml) (V1) and pour it into a weighing bucket containing 25 g of dry noodles. The volume was measured again (V2). The volume of the noodles was calculated by finding the difference between the total volume (V2) and the volume of water.

Optimal cooking time

Cooking quality of a noodles were analyzed according to the American Association of Cereal Chemists (AACC), (2000) method and according to method of Baskaran et al., (2011). The time required for the noodle core to disappear, when pressed softly between two glass plates after cooking, is the optimum cooking time (OCT). The cooking period began as the noodles were put into boiling water. 300 mL tap water was taken in a beaker and then 25 grams of noodle was cooked to optimum time. The noodle sample was boiled in a bowl at 100ºC temperature and time was recorded. One strip of noodle was crushed in every 1-minute interval for checking the cooking time. After this, they were rinsed for 15 minutes in cold water before weighed. Percentage of increased weight was calculated as a cooking yield.

Cooking loss

Cooking losses were analyzed according to AACC 66-50 (2000) procedure. 25g noodles cooked in 300ml boiling water at Optimal Cooking Time (OCT). The boiled water was collected in a beaker and then evaporated overnight in a hot air oven at 105°C until constant weight was reached, and the solids in the boiled water were determined. Cooking loss is expressed as a percentage based on the weight difference between final solids and initial dry matter.

Swelling index (%)

The swelling index of cooked noodles was evaluated using a protocol established by Cleary and Brennan (2006). It is calculated by subtracting the weight of the cooked noodles from the weight of the noodles after drying and then dividing by the weight of the noodles after drying.

Volume of cooked noodles (ml)

Volume of cooked noodles was determined by cooking 25g of dried noodles in a known amount of water.

Per cent (%) increase in volume

The per cent increase in volume of cooked noodles was determined by the difference between volume obtained from the cooked noodles and volume of noodles after drying followed by division of volume of raw noodles.

3.16 Sensory Evaluation:

A sensory evaluation was performed to determine overall consumer acceptance of the final product. The tasting committee evaluated consumer acceptance of the developed product. The panel test was conducted on the premises of CVASU, and the participants on the panel were students as well as teachers. A product obtained from hog plum peel was presented to 10 panelists. Excluding controls, there were three compounds coded as Sample A, Sample B, and Sample C. All participants in the tasting tried four samples without knowing their recipe. The samples were boiled in boiling water for 3 to 4 minutes, then fried with seasoning, and the qualitative characteristics (color, texture, taste, aroma) of the cooked noodles were compared with those of the control sample and evaluated. Optimally cooked noodles were analyzed for overall acceptability of the sample by 10 participants using a 9-point hedonic scale.

The scale was organized in such a way that:

Table 3.2: Rating Scale for Sensory Evaluation (Ref: Society of Sensory Professionals)

Rank	Scores
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

3.17 Statistical Analysis:

Data collection and storage for statistical analysis was performed in a Microsoft Excel 2019 spreadsheet, and descriptive statistics (mean and standard deviation) were calculated for the sample. Information was constructed, coded, and recorded using MINITAB 19. We then statistically analyzed the results of these experiments.

Approximate physicochemical composition, mineral content, phytochemical composition, and sensory evaluation data were analyzed by one-way ANOVA, and the size of significant variance was estimated with a 95% confidence interval. Statistical analysis was conducted at the 5% significance level ($p<0.05$).

CHAPTER 4
RESULTS

4.1 Weight of Peels

The obtained amount of dried powder is 377 grams from total fresh peel of 950 grams. So, the obtained powder from hog plum peels is 39.68%.

4.2 Proximate Analysis of Peels

The composition of hog plum peel has been analyzed by AOAC method, 2016. Table 4.2 demonstrates the results of proximate analysis of fresh fruit peel.

4.3 Bioactive Properties of Peels' Ethanolic Extract

Table 4.1 shows the result of Total Polyphenolic Content (TPC), Total Flavonoid Content (TFC) and DPPH radical scavenging qualities of Hog Plum peel extract.

Table 4.1: Bioactive compounds in peel extract

Properties of Peel Extract	**Value**
Total Polyphenol Content (mg GAE/100g)	3.794±0.01
Total Flavonoid Content (mg QE/100g)	183.433±0.67
Anti-oxidant Capacity (mg TE/100g)	1.474±0.02

4.4 Proximate composition of Peel Fortified Noodles

Table 4.2 shows the results for the proximate composition for formulated noodles used in the study. The proximate moisture composition ranged from 7.03% to 9.18%, crude protein ranged from 14.40% to 14.93%, crude fat ranged from 5 .04% and 7.33%, ash content ranged from 0.4% to 1.43% and crude fiber content ranged from 0.4% to 1, 43% %. and 3.56% of dry matter. The data showed that crude protein was not significantly different, but the composition of ash, crude fat and crude fiber varied among the enriched noodles samples.

Table 4.2: Proximate composition of fruit peel and developed product

Sample	**Moisture (%)**	**CHO (%)**	**Crude Protein (CP) (%)**	**Crude Fiber (CF) (%)**	**Crude Fat (%)**	**Ash (%)**
Fresh Peel	7.36	63.08	4.25	20.77	2.24	2.30
Control (0%)	7.06 ± 0.15^{d}	72.03 ± 0.2^{a}	14.93 ± 0.15^{a}	0.53 ± 0.17^{d}	5.04 ± 0.3^{d}	0.41 ± 0.15^{d}
Sample A (2.5%)	7.15 ± 0.14^{c}	70.91 ± 0.3^{b}	14.82 ± 0.12^{b}	1.22 ± 0.3^{c}	5.14 ± 0.36^{c}	0.76 ± 0.3^{c}
Sample B (5%)	8.72 ± 0.2^{b}	68.04 ± 0.25^{c}	14.75 ± 0.24^{c}	1.50 ± 0.3^{b}	6.05 ± 0.25^{b}	0.94 ± 0.43^{b}
Sample C (10%)	9.15 ± 0.33^{a}	64.16 ± 0.28^{d}	14.40 ± 0.26^{d}	3.54 ± 0.25^{a}	7.33 ± 0.38^{a}	1.42 ± 0.3^{a}

Values are expressed as mean ± standard deviation. Different superscript letters in the same column shows the significant ($p \leq 0.05$) difference among the variables based on HSD-Tukey Test.

4.5 Mineral content in Peel fortified Noodles

Table 4.3 demonstrations data happening for the chemical arrangement of the noodle samples used in the study. Fe content range is 55.2-78.1 µg/100 g, Zn content range is 0.15-0.18 ppm, Ca content range is 1.73-4.12 mg/100 g, K content range is 0.23-2.83 mg/100 g, Mg 1.47-4.05 mg/ 100 g and P 1.22 to 3.52 mg/100 g.

Table 4.3: Mineral Composition of Developed Product

Sample	Mg (mg/dL)	P (mg/dL)	Fe (µg/dL)	K (mmol/L)	Ca (mg/dL)	Zn (ppm)
Control (0%)	1.47 ± 0.02^{c}	1.62 ± 0.03^{a}	55.2 ± 0.1^{d}	0.23 ± 0.04^{d}	1.73 ± 0.03^{d}	0.15 ± 0.03^{d}
Sample A (2.5%)	1.72 ± 0.02^{c}	1.50 ± 0.03^{b}	60.7 ± 0.2^{c}	1.93 ± 0.03^{c}	1.92 ± 0.03^{c}	0.16 ± 0.05^{c}
Sample B (5%)	2.20 ± 0.26^{b}	1.46 ± 0.02^{c}	62.1 ± 0.05^{b}	2.42 ± 0.03^{b}	2.63 ± 0.03^{b}	0.17 ± 0.03^{b}
Sample C (10%)	4.05 ± 0.02^{a}	1.30 ± 0.02^{d}	78.1 ± 0.1^{a}	2.83 ± 0.04^{a}	4.12 ± 0.03^{a}	0.18 ± 0.04^{a}

Values are expressed as mean ± standard deviation. Different superscript letters in the same column shows the significant ($p \leq 0.05$) difference among the variables based on HSD-Tukey Test.

4.6 Total Phenolic Content of Peel fortified Noodles

According to Figure 4.2, the TPC is functionally higher the higher the peel extract content. The highest amount of polyphenols were found in the noodles that had 10% hog plum peel extract added to them (Sample C). Sample A's noodles with 2.5% hog plum peel extract added to them showed nearly the same levels of TPC as the noodles with 5% hog plum peel extract (Sample B). Moreover, control noodles without peel extract had the least amount of polyphenols, as can be shown.

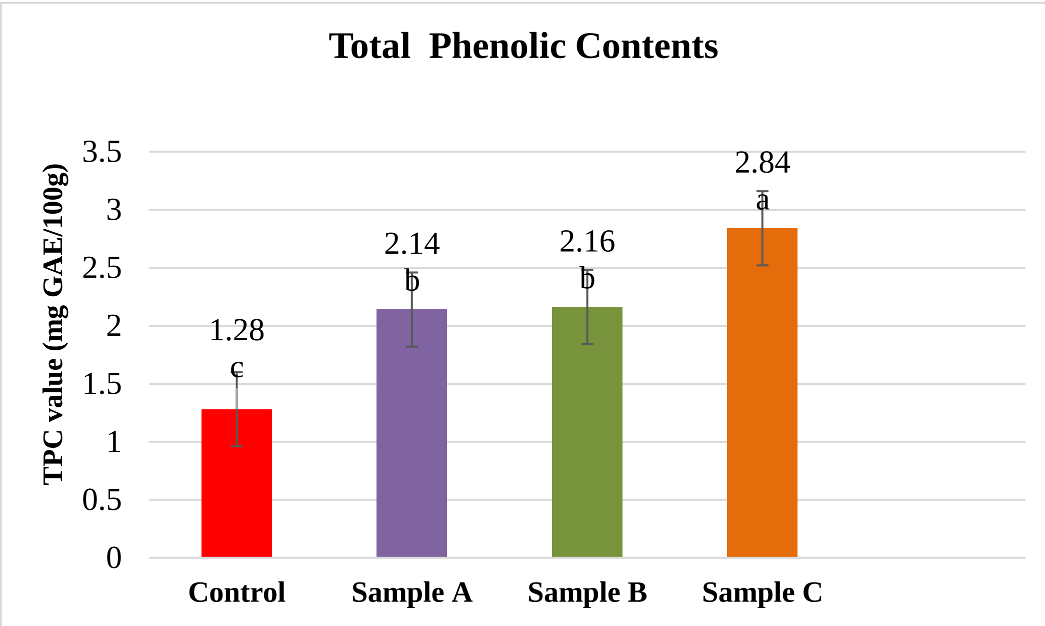

Figure 4.1: Total phenolic content of functional noodles with significant (p ≤0.05) difference.

4.7 Total Flavonoids Content of Peel fortified Noodles

Figure 4.3 depicts that, As the level of peel fortification increased, so did the TFC of fortified noodles. Highest TFC was observed to be at sample fortified with 10% of hog plum peel (Sample C). Additionally, it was noted that the least amount of flavonoids were present in the control noodles, which lacked peel extract.

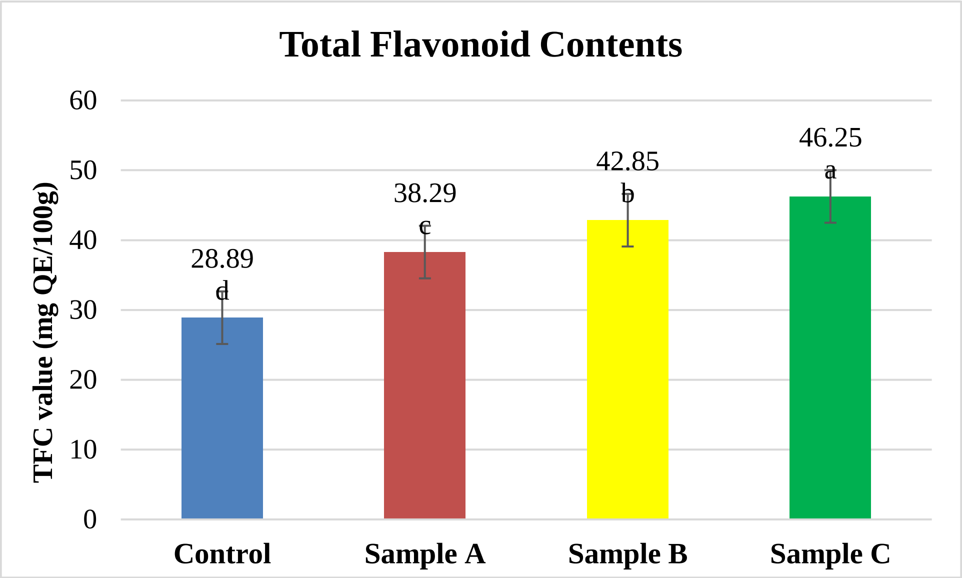

Figure 4.2: Total flavonoid content of fortified noodles with significant ($p \leq 0.05$) difference.

4.8 Anti-oxidant Capacity in Peel fortified Noodles

According to the data in Figure 4.4, the antioxidant capacity of Noodles with 10% enrichment (Sample C) was the highest (2.854 mg TE/100 g), whereas the antioxidant capacity of sample with no peel powder (Control) was the lowest (0.72 mg TE/100 g).

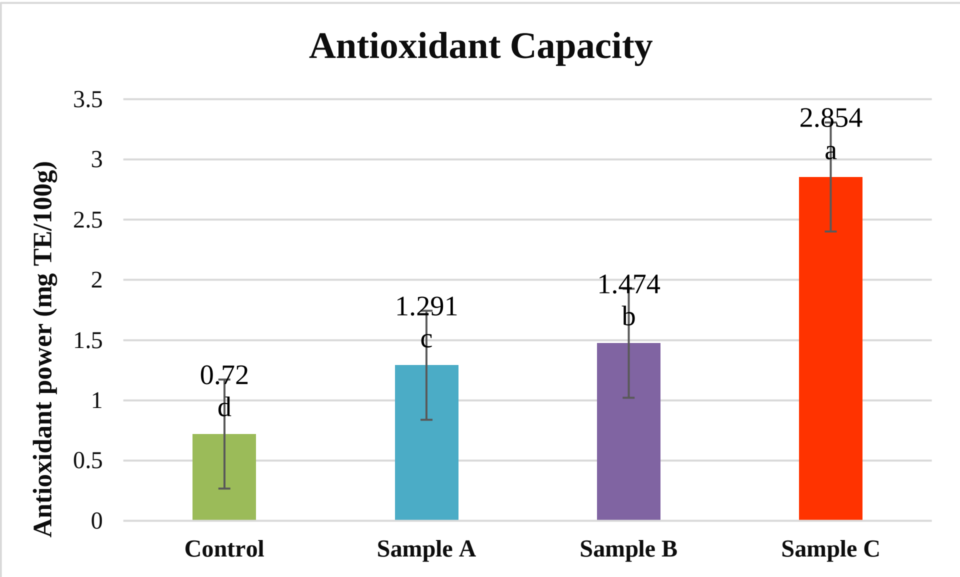

Figure 4.3: Antioxidant power of functional noodles with significant ($p \leq 0.05$) difference.

4.9 Cooking properties of Fortified Noodles

The data in Table 4.4 shows the impact of adding hog plum peel flour on the volume of noodles, cooking time, swelling power, and cooking loss of noodles after cooking.

Table 4.4: Cooking attributes of developed product

Sample	Cooking Time (min)	Swelling Index (%)	Volume increase (%)	Cooking loss (%)
Control (0%)	4	1.61	24.17	0.79
Sample A (2.5%)	3.30	1.49	22.05	1.43
Sample B (5%)	3.00	1.40	20	1.59
Sample C (10%)	2.50	1.21	16.92	2.32

4.10 Sensory Quality Evaluation

The ANOVA test revealed that Sample B and Control significantly differed from each other in terms of look, taste, smell, and texture but did not significantly differ from each other in terms of general satisfactoriness. However, on all dimensions including overall acceptability, Sample A outranks all other samples. Compared to the other samples, sample C had the lowest pass rate (Table 4.5).

Table 4.5: Organoleptic properties of developed product

Sample	Appearance/ Color	Flavor	Smell/ Aroma	Texture/ Mouthfeel	Overall Acceptability
Control	7.83 ± 0.05^{b}	7.33 ± 0.05^{b}	7.57 ± 0.05^{b}	6.68 ± 0.02^{c}	6.88 ± 0.03^{b}
Sample A (2.5%)	8.06 ± 0.05^{a}	7.83 ± 0.03^{a}	7.83 ± 0.05^{a}	8.19 ± 0.03^{a}	8.19 ± 0.02^{a}
Sample B (5%)	7.31 ± 0.02^{c}	7.17 ± 0.05^{c}	7.13 ± 0.05^{c}	6.88 ± 0.02^{b}	6.86 ± 0.05^{b}
Sample C (10%)	5.43 ± 0.05^{d}	5.43 ± 0.05^{d}	5.03 ± 0.05^{d}	5.47 ± 0.05^{d}	5.19 ± 0.04^{c}

Values are expressed as mean ± standard deviation. Different superscript letters in the same column shows the significant ($p \leq 0.05$) difference among the variables based on HSD-Tukey Test.

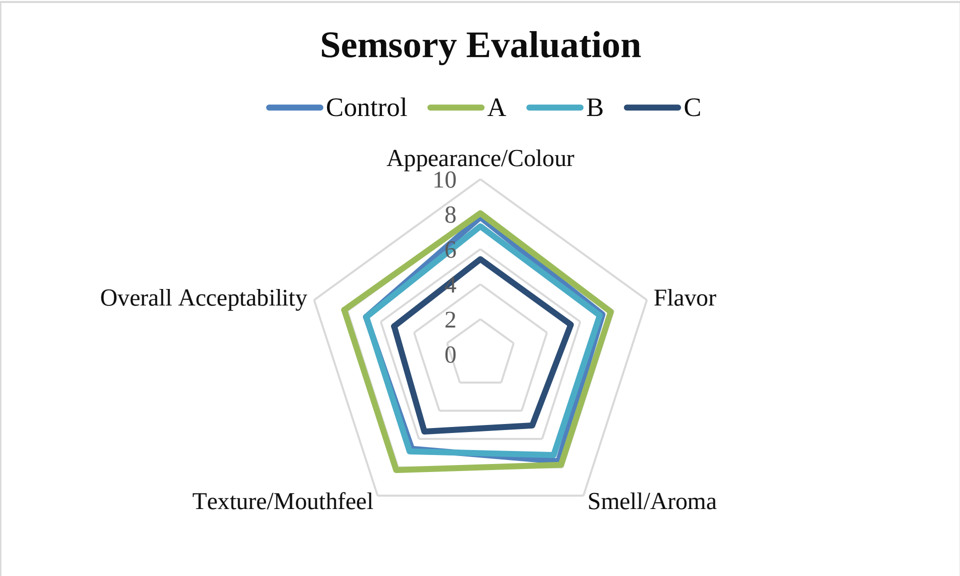

Figure 4.4: Sensory attributes of developed noodles

CHAPTER 5

DISCUSSIONS

5.1 Weight of Peels

A critical reduction in weight was watched when new peels were dried and milled into powder. The decrease in peel weight could be due to loss of moisture and thrashing of sample when crushing the dehydrated peels into powder. Drying has gotten to be a broadly utilized preparing strategy that can amplify the shelf-life of food products. "Higher drying temperature advanced shorter drying times, while longer drying periods were required at lower drying temperatures" (Garau et al., 2007; Barajas et al., 2012).

5.2 Proximate Analysis of Hog Plum Peels

For determining the quality of raw materials, estimation of proximate composition is important (Safdar et al., 2017). It is obvious from the proximate composition of hog plum peels that hog plum peel has higher moisture, ash, crude fat, and crude fiber contents but lower crude protein contents. Oladunjoye, et al. (2021) reported that hog plum bagasse contains ash (2.92%), crude fat (2.05%), crude fiber (25.73%), crude protein (7.29%), moisture (8.81%) and NFE (54.20%). It is possible that different varieties, climatic factors, topographical locations and agronomic techniques have contributed to the alteration in the proximate make-up of hog plum rind from one study to another.

5.3 Bioactive Compounds of Hog Plum Peel Extract

Polyphenols and Flavonoids Content

Hog Plum waste contains significant amounts of phenolic compounds and flavonoids. These biologically active compounds possess multiple biological properties including antioxidant, antibacterial, anti-inflammatory, cytotoxic and anticancer activity (Saxena et al., 2013).The TPC and flavonoids within Hog Plum Peel (HPP) extract accounted for 3.794 mg/ 100g GAE and 183.433 mg /100g QE compared to Gallic and quercetin respectively. Akinlolu-Ojo, T., et al. (2022) reported that, total flavonoid content (TFC) ranges from 0.06–0.13 mg RE/g and the total phenolic content (TPC) ranges from 0.76

to 2.02 mg GAE/g. Inclusion of fruit peel increased the concentrations of both TPC and TFC. This result is consistent with results previously reported by Villa-Hern'andez et al. (2017), where they demonstrated that the TPC and TFC capacities of the pericarp were higher compared to the pulp of Spondias purpurea L.

Antioxidant Assay

Fruit peel extract had a 1.474 mg TE/100 g antioxidant capacity, and its 32.72% inhibition rate. This outcome is comparable to that previously reported by Pasha, Imran, et al. (2022), who demonstrated that BPP had much better DPPH radical scavenging activity than WF (17.82% inhibition) in an in vitro antioxidant assay. The inhibitory capacity of DPPH was raised by 13% upon the addition of 15% (w/w) BPP to WF. These findings were consistent with those of Ajila et al. (2010), who reported that the inclusion of mango peel improves the radical scavenging activity of DPPH.

5.4 Proximate Composition of HPP Noodles

According to study findings, supplementing with HPP had a substantial impact on levels of water, protein, and fat (Table 4.2). Because HPP contains more fiber than WF, there may be a minor increase in moisture content of peel-enriched noodles (e.g., 7.06 and 9.15% in control and sample C, respectively (Happi Emaga et al. 2007). Decrease in protein content of HPP composite noodles, but not significantly. i.e., 14.93% (control) to 14.40% (sample C), shows that hog plum peel is low in protein, only 4.25% as mentioned above. 10% HPP compound flour noodles had about 5 times the crude fiber content with about 3.5% lower caloric value than 100% WF noodles. A higher fiber content is expected, since fruit waste is an excellent source of dietary fiber, which can improve the functionality of the final product (Cheok et al., 2018; Garcia-Amezquita et al., 2018). Low-calorie foods help prevent and manage various metabolic syndromes (e.g., hypertension, high blood sugar levels, and higher body mass index) (Liaquat et al. 2022). The mineral content of the functional noodles increased significantly, and the 10% HPP noodles had a 246% higher ash content than the control (100% WF). A higher ash content indicates a significant amount of minerals present in the bagasse, such as calcium, magnesium and iron (Esua et al., 2016). Our results were similar to the study reported by (Aurore et al. 2009) that BPP contains about 300 times more minerals than WF. Fat content was significantly higher in HPP than in WF, and increased by approximately 45% in composite flour noodles containing 10% HPP compared with control. The higher fat content of HPB could be attributed to the composition of the seed, as fruit seeds have been reported to contain a significant amount of fatty acids (Kaur et al., 2017; Morais et al., 2017). The results showed a similar trend to that previously reported by Ndife et al. (2011). Noodles with a high fat content are undesirable because they tend to go rancid during storage, giving the food an unpleasant odor (Gotoh et al. 2007). In this context, higher HPP levels do not seem to be suitable for added value on the fortification purpose.

5.5 Improvement of Mineral Content in HPP Noodles

Minerals are essential for human nutrition since they sustain our bones and regulate metabolic processes, claimed by Gupta and Gupta (2014). Since,cereal-based foods don't contain enough minerals to meet human needs, a growing reliance on them is primarily linked to mineral deficiencies (Ahsin et al. 2020). K (1.4 mmol/L), Ca (1.4 mg/dL), Fe (33.4 g/dL), Mg (2 mg/dL), Zn (0.13 ppm), and P (0.8 mg/dL) were the minerals identified in the powdered hog plum peel. Composite flour noodles (Sample C) had Fe, Mg, and K concentrations that were 29, 64, and 93% higher after the addition of 10% HPP when compared to the control, while Zn concentrations were slightly enriched and P concentrations were decreased by 20 and 19%, respectively. According to Umerah and Nnam's (2019) report on some underutilized fruits, the calcium and magnesium values obtained were comparable. The addition of fruit peels contributed a chief role in enrichment for some of the minerals. According to reports (Ismail et al. 2014), adding fruit peels rich in microminerals to WF is a sustainable way to raise the mineral content.

5.6 Bioactive Properties & Antioxidant Capacity in HPP Noodles

The enriched noodles with hog plum peel contain significant amounts of phenolic and flavonoid compounds. Compared to control noodles (1.28 mg GAE/100g), 10 percent HPP Noodles had a significantly higher total phenolic content (2.84 mg GAE/100g) (Fig. 4.2). The TPC in composite four noodles (Sample C) rose by up to 55% in comparison to control. Much greater TPC in BPP has been observed in the literature, with a range of 5-47 mg GAE/g. Mosa and Khalil, Hernández-Carranza et al., and other authors, 2015; 2016). Surprisingly, the TPC concentration of banana peel is 1–3 times higher than that of the flesh (Sulaiman et al. 2011). Flavonoids can both prevent cell damage and repair DNA damage, according to Panche et al. (2016), and HPP noodles have a lot more of them than WF noodles (TFC=46.25 mg QE/100 g) (Fig. 4.3). Moreover, the TFC in noodles increased by 55% when 10% HPP was added to WF. The TFC detected in BPP was much lower than that in banana peel data (467–756 EC/100g), pointing to the possibility of relationships between cultivar, fruit maturity, soil health, and postharvest management (Huang et al. 2005; Someya et al. 2002). Following the addition of 10% HPP in WF, the antioxidant capacity of noodles improved by 74.77% (Fig. 4.4). According to Sergio Dantas, De Oliveira Jnior, et al. (2021), the film based on natural pectin from hog plum demonstrated antioxidant capacity by scavenging the DPPH radical with a value of 15.48 1.48 mol TE/g. In a similar study, Suman& Rajinder (2015) added three levels of apple pomace powder (APP) to noodles. APP has been recommended as a valuable source of antioxidants due to its significant amount of phenols and flavonoids that enhance the antioxidant activity of cotton. It is also a great source of protein and dietary fiber.

5.7 Effect on Cooking Attributes of HPP Noodles

Cooking Time

The evaluated cooking characteristics of the control and 10% noodle samples were displayed in Table 4.4. The disappearance of the noodles' center while cooking indicates that the food has finished cooking. Noodle samples were found to follow Optimal Cooking Time for a maximum of 2 to 4 minutes. Since the optimal cooking time was only 2 min. 50 sec compared to the 4 min control, it was confirmed that the cooking quality of the functional noodles with 10% hog plum peel powder was reduced.

Swelling Index

When starch and protein are cooked together, water is absorbed by both, causing the starch to gelatinize and the protein to hydrate. The noodle swelling index is a measure of water absorption. The maximum swelling index was recorded in the control group (1.61%), followed by sample A (1.49%), sample B (1.40%) and sample C (1.21%) at the same level (Table 4.4). The swelling index of the side with the different treatments shows a significant difference between the samples at $p<0.05$. With higher levels of incorporation peel powder, the swelling index of the functional noodles decreased. These results line up with those of the instant noodle study published by Kamble, Vittal, et al. (2018).

Cooking Loss

Cooking losses play a critical role in determining a product's capacity to hold water in times of preparation and straight affect the produce of the finished product. Cooking losses counted for compound flour noodles in this experiment amplified, but only slightly by about 2.32%; compared to WF noodles (Control) (Table 4.4). Cooking loss was found to increase along with the level of hog plum peel powder incorporation. Weak protein-starch interaction or a degraded protein matrix may be to blame for this. Furthermore, the high water soluble protein fraction, fiber, and mineral content of hog plum peel powder may be the cause of the high cooking loss of peel powder-incorporated noodles when compared to the control. According to Ovando-Martinez. et. al (2009), increased cooking loss can happen when durum wheat semolina is partially or entirely replaced with fiber material. The results of this study's investigation into cooking loss are consistent with the Turkish noodle standard, which states that cooking loss shouldn't be allowed to exceed 10% of dry matter. Park and Baik (2009) found that soft wheat flour with a 6% gluten concentration reduced cooking losses by 15%. In another study, it was reported as BPP contained less amylose starch than usual, there was more leaching, which could account for the increase in cooking losses (Lucisano et al. 2012).

Volume Increase

The information in Table 4.4 relates to the volume of cooked noodles produced when hog plum peel powder is added to wheat flour. The volume of the cooked noodles varied between the treatments. The highest volume of cooked noodles was found in Treatment T1 (24.17%), followed by Treatments T2 (22.05%) and T3 (20%), and the lowest was discovered in Treatment T4 (16.92%). The results presented here are consistent with those of Kumble, Vittal and their colleagues. (2018) found that the low amount of noodles containing drumstick leaf flour may be a result of replacing wheat flour with drumstick flour, which reduces the starch content of flour and reduces the swelling ability of flour, thereby lowering the volume of cooked noodles.

5.8 Sensory Qualities of HPP Noodles

The organoleptic analysis revealed that noodles made with 5 percent HPP were quite comparable and palatable (6.86) in comparison to controls (6.88). Noodles can have up to 10% of hog plum peel added to them, but excessive fiber content restricts negatively with the starch matrix resulted from flour and lowers the texture, taste, and appearance scores of the noodles (Table 4.5). Higher fiber content results in a lower texture score (5.47), which lowers the overall acceptability (5.19) of compound noodles get enriched with 10% HPP. The sensory attribute results for noodles with a 2.5 percent HPP content showed that they had the best taste (7.83). Sample A (2.5 percent supplementation) received the highest score for appearance according to the sensory data score, which was evident. Sample A received the highest score for texture, taste, and aroma, which reflect the product's senses. The overall acceptability scores of the four samples differed slightly from each other. Similar results were obtained with other flour according to (Pasha et al., 2022). Fructose, glucose and protein are present in higher concentrations in banana peel powder (Happi Emaga et al., 2007). It becomes vulnerable to Maillard reactions during powder manufacture, and pre-existing oxidative enzymes also contribute to enzymatic browning (Thipayarat 2007). Although HPP includes more dietary fiber than other supplements, softness also decreased with supplementation.

CHAPTER 6
CONCLUSION

This research suggests that hog plum peels can be used to obtain polyphenols in a similar manner to how orange, pomegranate, and apple peels are. The extracted polyphenols contained significant amounts of TPC and TFC. Because it has low production costs, commercial polyphenol extraction has the possibility of use in the food industry. The sensory perception of the hog plum peel noodles prepared with the extracted polyphenols was similar to that of the control, and the immediate result was also consistent with the control, according to this study. The noodles made with 2.5 percent HPP have the highest acceptability and the longest shelf life. Commercial fruit peel noodles could not be tested in this study because they were not sold in the local markets. The fiber from hog plum peel might improve the finished product.

CHAPTER 7
RECOMMENDATIONS AND FUTURE PERSPECTIVES

This experiment has yielded promising results in the emerging field of creating new technologies to add value to fruit. It also increased its commercial value and acceptance. Recommendation of this study are-

- ✓ The sample (fruit peel) should be collected in a clean sampling bag and stored in the freezer to avoid microbial attack
- ✓ Fresh, mature fruit peels should be used as over-ripe fruit does not contain many bioactive compounds
- ✓ UAE method can be performed for better yield of peel extract
- ✓ Moisture content should be kept in the range of 10% to 15% while noodles are drying. Hard noodles strips can be produced at moisture levels below 10%.
- ✓ Stirring should be continued during noodles steaming. Otherwise, lumps formation could be occurred

Future perspectives are-

- ➢ Some other bioactive compounds (such as anthocyanin, spondiol) would be characterized from peel sample
- ➢ Anti-microbial properties could be studied for peel sample and developed noodles sample
- ➢ Future research should be focused on color determination by HunterLab colorimeter as color changes intensely with the inclusion of peel
- ➢ More work could be performed on firmness of noodles analyzed with the help of Texture Profile Analyzer
- ➢ SEM might be employed for screening microstructure of noodles
- ➢ Glycemic Index (GI) of formulated noodles could be checked to improve the nutritional aspects

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Appendix

Appendix A: Preparation of peel fortified noodles:

Fresh Fruit Peel

Peel dissolved in KMS

Dried peel

Peel Powder

Peel Extract

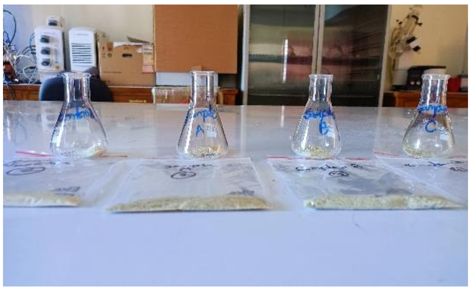
Dough Proofing

Extrusion

Extruded Noodles

Final Product

Appendix B: Laboratory works:

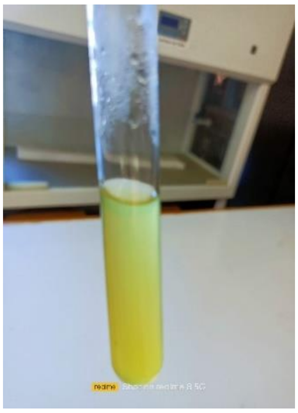


Sample Preparation

TPC Determination

Sample Preparation for UV visible Spectrophotometer

Titration for Proximate Analysis



TFC Determination

Steaming

Volume Determination

Appendix C: Sensory evaluation of peel fortified noodles

Panel Members

Brief biography

Eka Mazumder graduated with a B.Sc. (Hons.) in Food Science and Technology from Chattogram Veterinary and Animal Sciences University (CVASU) in Chattogram, Bangladesh with a CGPA (Cumulative Grade Point Average) of 3.93 on a scale of 4.00. She previously completed the Higher Secondary School Certificate (HSC) Examination in 2015 with a GPA of 5.00/5.00 after passing the Higher Secondary School Certificate (SSC) Examinations in 2013 with a GPA of 5.00 / 5.00. She briefly declared herself a candidate for Masters Degree in Food Processing and Engineering at Department of Food Processing and Engineering, Chattogram Veterinary and Animal Sciences University (CVASU), Bangladesh. She has a strong passion for sharing information and scientific research and would welcome any other opportunity to do so.