CHARACTERIZATION OF DRIED UNRIPE BANANA PEEL AND ITS APPLICATION IN THE DEVELOPENT OF VALUE-ADDED NOODLES.

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BY

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Kolkata

Dated: 14-09-2023 **PAULAMI CHAKRABORTY**

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INTRODUCTION

1.1 INTRODUCTION

One of the most common fruit crops grown for its edible fruits in tropical and subtropical regions is the banana (Musa spp., family Musaceae [1]. It belongs to the genus Musa sapientum and the family Musaceae. It is a seasonal fruit that is primarily consumed when it is ripe. Both ripe and unripe bananas are processed into snacks and juice. After being harvested, bananas quickly deteriorate due to their high perishability. Due to improper post-harvest processing, large amounts of waste are produced before consumption and large amounts of fruits are lost during their commercialization. The pseudostem, leaves, inflorescence, fruit stalk, rhizome, and peels of bananas are banana biowastes. In 2019, 116 million tons of bananas will be produced worldwide, and the banana fruits will be harvested.

The average fruit weighs 125 grams, of which about 75% is water and 25% is dry substance. When ripe, bananas come in a variety of sizes and hues, including yellow, purple, and red. However, practically all bananas used for cooking have fruits without seeds, whereas wild varieties have fruits with many of huge, difficult seeds [2]. The fruits are used in baking and can be consumed raw, boiled, dried, or powdered into flour [1, 2]. In addition, green or unripe bananas are used to make starch and cook a variety of recipes [1, 2]. Animal diet contains plant components and banana peel [1, 2].

The major amount of the bananas exported from the tropics and subtropics are of the Cavendish cultivar, which is the most significant banana cultivar. According to estimates, 30–40% of the overall production of bananas is discarded because it doesn't match quality criteria. Green fruits are wasted fruit and are available to cattle since they disintegrate more quickly than ripe fruits [3,4]. B6, C, and potassium are among vitamins that are abundant in bananas. The banana peel, which makes up around one-third of the weight of this food and is thrown away as trash, is the sole subject of this study. Here, banana peels are chosen for the production of products like noodles because of their high nutritional content and antioxidant characteristics. This comes after choosing an appropriate drying procedure and producing flour. The anti-oxidant properties of flour are also being studied here.

Banana Peels:-

The outside (cover) of the banana fruit is known as the banana peel. It is a by-product of domestic use and banana processing [5]. Animals eat it for food. Additionally, banana peels are utilized in the creation of inorganic waste, numerous biochemical products, cooking, and water filtration [5,6]. Sometimes, banana peels are used as a source of food for animals, including goats, monkeys, chicken, rabbits, fish, zebras, and many other species [1].

Nutritional Value of Banana Peel :-

The nutritional value of banana peels varies depending on the cultivar and maturity stage, since the lignin concentration rises with ripening (from 7 to 15% dry matter) and the plantain peel has less fiber than dessert banana peels. 6-9% protein and 20–30% fiber are both present in dried banana peels. 40% of the starch in green plantain peels is converted into sugars during ripening. Ripe banana peels can contain up to 30% free sugars, but green banana peels have significantly less starch (approximately 15%) than green plantain peels [7]. Banana peels are used to make ethanol [9], cellulase [10], laccase (poly copper oxidase) [11], fertilizer [12] and fertilizing [13], as well as for water filtration [8].

Chemical Composition of Banana Peel :-

Banana peel, Musa sapientum, has been found to contain a variety of vitamins and minerals [14]. The banana peel contains 1.95 % crude proteins, 5.93 % crude fat, and 11.82 % crude carbohydrates. Banana peels contained the minerals phosphorus, iron, calcium, magnesium, and sodium. Manganese, zinc, copper, potassium, and other elements were discovered in extremely small amounts as mg/100 g (Figure 1) [21]. Potassium is the most significant mineral included in banana peels .

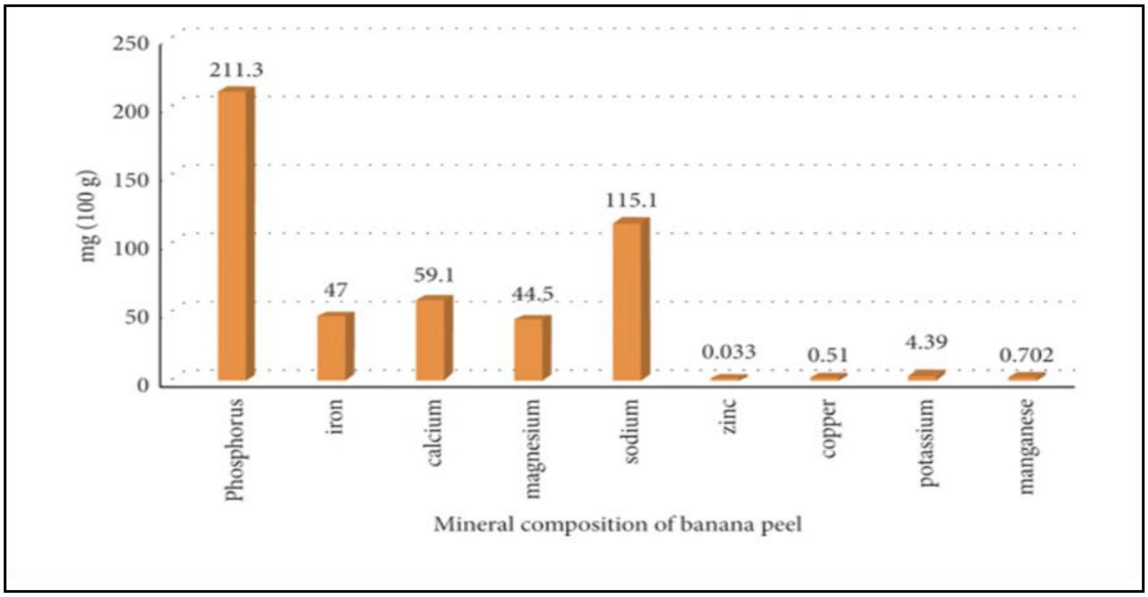

Fig. 1: Mineral Composition of Banana Peel.

The significant quantities of amino acids such as leucine, valine, phenylalanine, and threonine. Figure 2 shows the chemical structures of amino acids found in a banana peel: leucine, valine, phenylalanine, and threonine. [26]

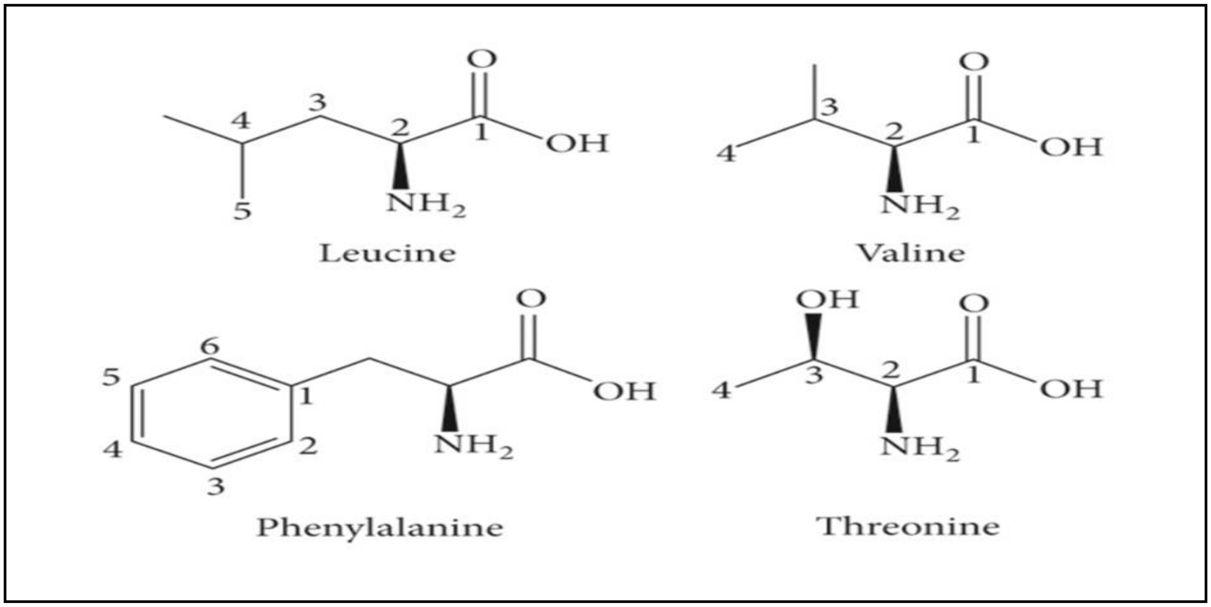

Fig. 2: Different Amino Acids present in Banana Peel.

Antioxidant Property: -

The banana peel is a rich source of chemical substances including antioxidants. Banana peels (Musa acuminata Colla AAA) contain phenolic compounds in amounts ranging from 0.9 to 3.0 g/100 g dry weight [15,16]. Additionally, gallocatechin was discovered by Someya et al. [16] at a concentration of 160 mg/100 g dry weight. Anthocyanins (delphinidin and cyanidin), as well as catecholamines, are other substances found in the peel of ripe bananas (Musa acuminata Colla AAA). On the other hand, sterols and triterpenes like -sitosterol, stigmasterol, campesterol, cycloalkanol, cycloartenol, and 24-

methylenecycloartanol as well as carotenoids like -carotene, -carotene, and various xanthophylls have been discovered in the banana peel [19, 20].

The total phenolic content of the peels of 15 different banana cultivars produced in Brazil ranged from 29.02 to 61.00 mg GAE/100 g for unripe bananas and from 60.39 to 115.70 mg GAE/100 g for ripe bananas [21]. Additionally, a total phenolic content of 20.47 mg gallic acid equivalents (GAE)/100 g was found in 8 Malaysian banana cultivars [22]. Ferulic acid (0.38%) and caffeic acid (0.06%), phenolic compounds found in banana peel extract [23,24], as well as other phenolic compounds such catecholamines and anthocyanins [25], are present in plantain banana peel flour, which has a total phenol content of 7.71 mg GAE/g. The chemical composition of banana peels is depicted in Figure 3 [23].

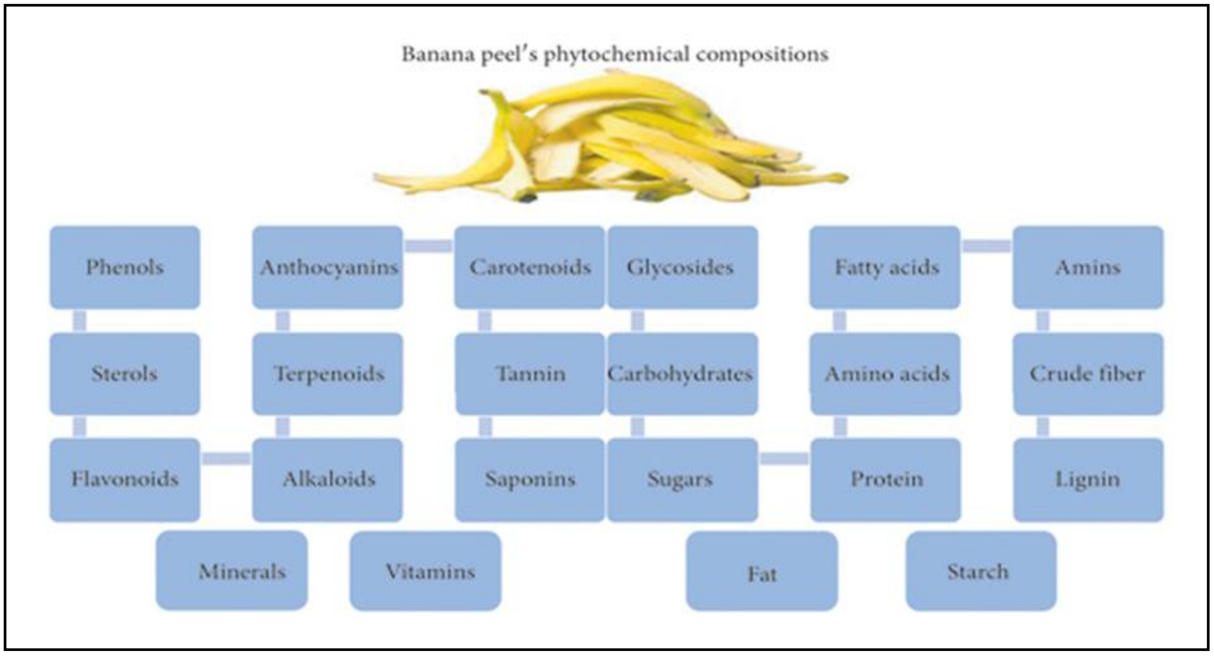

Fig. 3: Phytochemical Components present in Banana Peel.

DRYING

The primary objective of this work was to produce flour from BPP using various drying techniques, for which the kinetics were also investigated.

Drying, one of the oldest methods of food preservation, keeps food from spoiling by removing moisture, which is necessary to keep the plant viable for future use. Depending on the drying technique, moisture, antioxidant content, color, and texture all change [26,27]. Many fruits and vegetables have been dried using the vacuum drying technique since it helps to increase the quality and nutritional content of produce [28, 29].

Sublimation is used in freeze-drying to dehydrate the product. The main causes of a product's prolonged shelf life without microbial degradation are the lack of liquid water and low temperature, which improves the product's quality. Despite its many benefits, freeze drying has been found to be the most expensive drying method. The cost of freeze-drying is mostly influenced by the type of product, packaging, plant capacity, etc. [30]. The level of electricity usage was used to assess the cost of each drying procedure. Persimmon chips that were frozen-dried consumed 7-9 times more energy than those that were dried using hot air or hot air and a microwave. The usage of the hot air-drying method is relatively simple, and it is affordable also [31]. In microwave drying, the inside of the product is heated first by electromagnetic radiation then the heat spreads out and internal vapor pressure is generated that removes the moisture from the product [32]

The drying kinetics is used to describe the combined macroscopic and microscopic mechanisms of heat and mass transfer during drying, and it is affected by drying conditions, types of dryer and characteristics of materials to be dried.

Studying drying kinetics is a means to choose appropriate drying methods and to control the processes of drying. It is also important for engineering and process optimization. Drying kinetics is used to show removal of moisture from products, and it has to do with process variables, and hence, a better understanding of drying rate will help in developing a drying rate model [33]. There are three drying models, namely, theoretical, semi-theoretical and empirical accordingly. Theoretical models dealt with internal resistance in transfer of moisture, while semi-theoretical and empirical models worked on external resistance in the transfer of moisture between air and products. Empirical model's main shortcoming is that it does not consider the basics of drying process but explains only the drying curve for drying conditions but not the processes that occur during drying [34]. Examples of semi-theoretical models are the Lewis model, Henderson and Pabis model, Logarithmic model, Page model, etc. The theoretical model that is commonly used in drying rate is Fick's second law of diffusion. Theoretical models have been found to be inadequate, tend to generate erroneous results and are complex for practical applications. Therefore, in food drying semi-theoretical models have been developed as a better model to fit the drying data of banana peels to be dried [35]. The drying kinetics models are therefore significant in deciding the ideal drying conditions, which are important parameters in terms of equipment design, optimization, and product quality improvement (36). So, to analyze the drying behaviour of fruits and vegetables it is important to study the kinetics model of each particular product. Thin-layer drying is a widely used method for determining the drying kinetics of fruits and vegetables involves simultaneous heat and mass transfer operations. During these operations, the material is fully exposed to drying conditions of temperature and hot air, thus improving the drying process. The most important aspects of thin-layer drying technology are the mathematical modelling of the drying process and the equipment design which can enable the selection of the most suitable operating conditions. Thus, there is a need to explore the thin-layer modelling approach as an essential tool in estimating the drying kinetics from the experimental data, describing the drying behaviour, improving the drying process.

NOODLES

The second most popular food in South Asia is rice products, followed by noodles. Since they started to appear in ethnic foods over the past ten years, noodle consumption patterns have also dramatically expanded among Westerners (37). Although wheat flour, which makes up a large portion of the recipe for the noodles, is thought to be a great source of carbs, it is deficient in important minerals, fiber, and amino acids, as was previously mentioned. As a result, numerous attempts to fortify noodles with other flours, including buckwheat, barley, coconut, sweet potato, rye, and soy flour, have been made [38, 39]. Incorporated flour noodles have significantly improved nutrition, when incorporation done with buckwheat, sweet potato or coconut etc. might add to the cost. Banana peel powder supplementation in noodles recipe is an innovative approach to increase their nutritional quality (40). Banana peel powder is nutritionally significant as it is enriched with micronutrients. Moreover, banana peel powder has higher water-holding, and swelling capacity owing to high soluble fibre content, required for the better-quality noodles (38). Fortification of wheat flour with banana peel powder can be a sustainable approach for improving nutritional profile (antioxidants, secondary metabolites, minerals, dietary fibre, and essential amino acids) of noodles (41). To the best of our knowledge, there is no literature mentioning the usage of banana peel powder in salted noodles. Therefore, the purpose of this study was to evaluate the nutritional value of locally produced banana cultivar peel, the effect of adding banana peel powder on functional qualities, and the sensory quality of noodles made from wheat flour and banana peel powder.

LITERATURE REVIEW

2.1 GENERAL

The different published works reported so far in literature on the green banana peel as a waste product utilization because of its high nutritional value. The different drying technics , drying kinetics of green banana peel and also the antioxidant activity of dried peel powder and development of noodles fortified with the banana peel powder and its characterization has been studied. Researchers are working on the topic for last 25 years. In this chapter an attempt has been made to review the past works on the relevant topic in chronological order.

2.2 STUDIES ON COMPOSITION AND NUTRITIONAL VALUE OF GREEN BANANA PEEL

In recent years, scientists' interest in agricultural waste has increased, and the waste has become attractive to explore and benefit from, rather than being neglected waste. Banana peels have attracted the attention of researchers due to their bioactive chemical components. One of the benefits that humans get from the work of scientists on plant waste is that the banana peel was able to draw attention as a source of functional and nutritional compounds.

Wafaa M et al (2022), suggested that the banana peels that can be used as good sources of natural antioxidants and for pharmaceutical purposes in treating various diseases. A member of the Musaceae family and an edible fruit, bananas are grown in tropical and subtropical climates. In the locations where they are grown, banana peels are fed to cattle as supplemental feed. By recycling agricultural waste, its huge by-products serve as a great supply of high-value raw materials for other sectors.

Anhwange, B.A. et al (2009), suggested that banana peels are rich in minerals, nutritional and anti-nutritional contents. The mineral content indicate the concentrations (mg/g) of potassium, calcium, sodium, iron, manganese, bromine, rubidium, strontium, zirconium and niobium to be 78.10, 19.20, 24.30, 0.61, 76.20, 0.04, 0.21, 0.03, 0.02 and 0.02 respectively. It also contains the percentage concentrations of protein, crude lipid, carbohydrate and crude fiber were 0.90, 1.70, 59.00 and 31.70 respectively. The results indicate that if the peels are properly exploited and process, they could be a high-quality and cheap source of carbohydrates and minerals for livestock.

2.3 STUDIES ON DRYING KINETICS AND ANTIOXIDANTS CONTENT OF BANANA PEEL

Nahar et al (2022), investigated the kinetics of drying and the extraction of antioxidants, energy-economical factors, quality parameters, and phytochemicals using ultrasound assistance under various drying procedures. Additionally, the literature claimed that using plant waste as a source of functional food required intense study.

Youssef et al (2018), investigated the effect of five known drying methods on the biological activity of banana peel to identify the suitable drying conditions giving dried peel has good physical properties, minimum loss of bioactive compounds and antioxidant properties. Their experimental results showed that microwave irradiation at the power level of 950 W for 6 min was the most suitable condition, as these dried peels had the highest antioxidants recovery and antimicrobial activity. This was followed by vacuum over drying at 65°C (8h), hot air over drying at 110°C (4h), and then dry air oven drying at 60°C (12h 30 min), and at last sun drying. Samples of peels dried by microwave possessed a total phenolic content of 26.88 mg (GAE/g DM), total flavonoids content of 31.81mg (QE/g DM), total monomeric anthocyanins of 5.34mg (CE/g DM) and total tannins content of 22.00mg (TE/g DM). Also possessed highest antioxidant activity at four concentrations of 80% methanol extract of banana peel (0.5, 1.0, 1.5 and 2.0 mg/ml) to scavenge free radical of DPPH in comparison to ascorbic acid. The inhibitory percentages were 15.40, 24.46, 44.95, and 65.22 mg/ml respectively. These findings unambiguously support the use of banana peel waste as a significant natural source of bioactive chemicals, but successful use requires both optimal drying conditions and the right solvent.

Adeyeye et al (2017), suggested that banana fruits are highly perishable, requiring preservation in some forms. Minimal processing, refrigeration and dehydration or drying are among the useful processes used in preserving banana fruits. Drying of banana fruits is used in reducing losses and improving food commercial value. Drying is the process of moisture removal due to simultaneous heat and mass transfer under controlled conditions. In spite of its age, drying is still a popular way to preserve food since it is straightforward, inexpensive, and easy to use. Bananas become less bulky through moisture loss during drying, which reduces volume and makes handling and processing easier. As a result, it is less expensive to package, handle, store, and transport goods. There are various drying methods, each with their own benefits and drawbacks. The complex phenomenon known as the banana drying kinetics is utilized to anticipate drying behavior and to optimize drying settings. The effectiveness of drying kinetics models in forecasting drying behavior and maximizing drying parameters of banana fruits is also evaluated in this body of literature.

Hang et al (2017), suggested the effect of different drying methods on the quality of banana peels. The physical, chemical, and antioxidant qualities of dried peels were considerably impacted by the various drying settings. Given that these dried peels had good physical characteristics, no loss of bioactive components, and antioxidant qualities, microwave irradiation at 960 W for 6 min was the ideal setting. After that came freeze-drying, vacuum ovens at 60 degrees, hot air ovens at 120 degrees, dehumidified air ovens at 60 degrees, and sun drying. The peels dried by microwave possessed a total phenolic content of 25.26 mg of gallic acid equivalents/g of dry matter (DM) and potent antioxidant capacity [(1,1-diphenyl-2-picrylhydrazyl) of 37.70; 2,2′-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid of 46.35; ferric reducing antioxidant power of 45.94; and cupric ion reducing antioxidant capacity of 64.55 mg of trolox equivalents/g of DM]. Therefore, the study recommends the use of microwave irradiation under the studied condition (power level of 960 W for 6 min) for further processing and utilization.

Saha et al (2016), suggested that . drying conditions significantly affected the physicochemical characteristics as well as bioactivities of Corn corb .For MWD products, direct absorption of electromagnetic energy by water molecules greatly accelerated the evaporation process, leading to a faster dehydration with a very high moisture diffusivity value. Additionally, the application of microwave markedly enhanced disintegration of cellular components manifested in lowered values of structural and color attributes.

Daniel et al (2016), suggested that a comprehensive review of modeling thin-layer drying of fruits and vegetables with particular focus on thin-layer theories, models, and applications since the year 2005. The thin-layer drying behavior of fruits and vegetables is also highlighted. The most frequently used of the newly developed mathematical models for thin-layer drying of fruits and vegetables in the last 10 years are shown. Subsequently, the equations and various conditions used in the estimation of the effective moisture diffusivity, shrinkage effects, and minimum energy requirement are displayed. The literature is very useful for future research in terms of modeling, analysis, design, and the optimization of the drying process of fruits and vegetables.

Prerna et al (2015), evaluated the quality and drying characteristics of culinary bananas at a range of temperatures (40-70°C) that showed a dropping rate period. Wang and Singh's drying model, which had the lowest 2 and greatest R2 values among the several drying models, was determined to be the best suited model. A new model that expresses moisture ratio as a function of time and temperature was developed after the coefficients of the Wang and Singh model were represented in nonlinear form as a function of temperature.

2.4 STUDIES ON DEVELPOMENT OF NOODLES FORTIFIED WITH BANANA PEEL POWDER

Balmurugan et al (2022), represented in their study that Noodles was developed by incorporating unripe banana flour at different incorporation levels of 5, 10, 15, 20, 25, 30, 35, 40 and 45 per cent and the prepared noodles were organoleptically evaluated. A 45 percent integration of unripe banana flour was found to be quite satisfactory based on organoleptic examination. The noodles made from unripe banana flour had 22.04% resistant starch, 8.49% moisture, 8.23% protein, 1.27 fat, 1.95 fiber, and 71.11% fiber. The cooking quality features of noodles made with banana flour substituted during storage revealed that the ideal cooking time was between 8.45 and 7.30 minutes, the gruel loss was from 5.31 to 5.67%, the water absorption was between 200.15 and 204.45 ml, and the rehydration ratio was between 2.0 and 2.22.

Pasha et al (2022), established that the substitution of wheat flour (WF) with banana peel powder (BPP) at supplementation rates of 5, 10, and 15%, and evaluated their suitability to develop salted noodles. The results showed that the composite flour with 15% BPP had significantly higher protein, ash, and crude fiber content as compared to control. Higher antioxidant capacity was observed in composite flour noodles: total phenolics content (TPC), total flavonoid content (TFC), ferric reducing power (FRAP) and DPPH reducing power were increased up to 278, 260, 143 and 13 percent respectively in the noodles containing 15% BPP as compared to control (100% WF). On the other hand, values for viscosity decreased up to 22% with addition of BPP in WF. Furthermore, water absorption capacity and cooking losses were increased up to 15 and 13 percent respectively with 15% BPP incorporation in WF. Results for sensory evaluation demonstrated that noodles with 10% BPP scored highest for sensory profile.

Biernacka et al (2020), suggested that to analyze the effect of dried banana powder (BP) on common wheat pasta characteristics. Wheat flour (type 500) was replaced with 1%, 2%, 3%, 4% and 5% of Banana peel . Control pasta without BP addition was also prepared. Pasta quality parameters including texture, colour, cooking characteristics and sensory evaluation were determined. Total phenolics content and antioxidant activity were also evaluated. The increase in BP in the pasta recipe resulted in an increase in the weight increase index (from 2.88 to 3.55) and cooking loss (from 5.2% to 6.4%). The effects of the addition of bananas were also observed in changes in colour coordinates. It was shown that BP slightly decreased the lightness of cooked pasta and had little influence on colour coordinates of raw pasta. It was also found that the addition of BP higher than 3% decreased pasta firmness. The total phenolics content and antioxidant capacity of pasta increased with the addition of BP. Sensory evaluation of pasta showed that the replacement of common wheat flour with BP should not exceed 3%.

Mudgil et al (2017), investigated that partially hydrolyzed guar gum (PHGG) obtained after enzymatic hydrolysis contained 80.04% soluble dietary fiber and 83.1% total dietary fiber. In this e study, the effect of process variables such as PHGG level (1–5%), water level (30–40%) and mixing time (2–6 min) on response variables i.e., cooking yield, cooking loss and overall acceptability of noodles were studied using response surface methodology. The second order model obtained for cooking yield, cooking loss and overall acceptability of noodles revealed coefficient of determination of 0.9796, 0.9446 and 0.7787, respectively. The optimum values for independent variables i.e. PHGG level, water level and mixing time were 2.23, 32.03% and 2.81 min, respectively. The findings demonstrated that adding 2.23% partially hydrolyzed guar gum as soluble fiber to noodles improved their sensory and textural qualities and reduced cooking yield and cooking loss.

Singh et al (2015), suggested to incorporate banana peels powder (BPP) in the preparation of noodles, to determine the nutrient composition of BPP and noodle as well as to assess the organoleptic quality and cost. The literature based on the experimental results showed that Noodles were made by incorporating BPP at three different ratios (Refined flour: BPP; 90: 10, 80: 20 and 70: 30 respectively) named as T1, T2 and T3. Noodles prepared from the refined flour only served as control (T0). The noodles were organoleptically evaluated by Nine Point Hedonic Scale. The nutritional composition of product was chemically analyzed by using the AOAC (2005) methods. Appropriate statistical technique was opted for the analysis. On the basis of sensory evaluation T1 (90:10) was most acceptable with regards to overall acceptability. At a 5% level of significance, there was a significant difference between the sensory characteristics of various treatments. Dehydrated BPP has the following approximate compositions: 7.76 g of protein, 9.8 g of carbohydrates, 244.68 mg of calcium, and 212 mg of phosphorus. The nutritional makeup changed as the BPP substitution level rose. Banana peel has a nutritional profile that suggests it can deliver natural calcium if taken as a supplement. It can be used to create a product with extra value. Therefore, banana peels can be used to their full nutritional potential.

Ramli et al (2009), findings on Banana Peel (BP) noodles made by partially replacing wheat flour with green Cavendish banana peel flour were characterized for physicochemical parameters and in-vitro starch hydrolysis. pH, color, tensile strength, elasticity, in-vitro hydrolysis index (HI), and estimated glycemic index (GI) of cooked noodles were all evaluated. Compared to the control noodles, BP noodles had lower L* (darker) and b* (less yellow) values. The BP noodles had a similar tensile strength to the control noodles but had greater elasticity. Studies on in-vitro starch hydrolysis revealed that BP noodles had a lower GI than control noodles. Controlling the starch hydrolysis of yellow noodles may be accomplished by partially substituting banana peel for the noodles.

2.4 NEED FOR PRESENT STUDY

From the above literature review it may be seen that's large number of works has been done abroad on different drying process, optimization of processes, selection of best fitted model of thin layer drying kinetics of banana peel . It also can be seen that huge study has been done also on product development by fortification with banana peel powder. Presently no such data is available on different parameters of noodles incorporated with banana peel powder. With this background present study aimed at studying the effect of various parameters like cooking yield, cooking loss of noodles and others drying kinetics parameters on thin layer drying of locally available banana peel .

OBJECTIVE AND SCOPE OF THE WORK

3.1 OBJECTIVES

The primary objective of this study was as follows

i) To study the different drying methods such as microwave drying, tray drying, freeze drying, vacuum drying along with different thin layer drying kinetics of Banana peel.

ii) To study the anti-oxidant property of Banana peel powder getting from different drying methods .

3.2 SCOPE OF THE WORK

To fulfill the above objective the drying processes are carried out with the different dryers:-

A) Microwave at different power level.

B) Tray dryer

C) Vacuum dryer

D) Freeze dryer

The scope of work for the present study are as follows:

The experiments were done with the unripe banana peel of locally available banana for determination of following parameters:

i) Moisture Ratio

ii) Anti-oxidant activity in terms of Gallic Acid

iii) Anti-oxidant activity in terms of Catechins

iv) Anti-oxidant activity in terms of DPPH

Conventional noodles maker machine is used for noodles making and then the noodles made at different composition in order to study the various parameters like:

i) Water absorption capacity

ii) Cooking yield

iii) Cooking loss

These parameters determine the best composition of noodles fortified with Banana peel powder.

CHAPTER-4

EXPERIMENTAL PROGRAMME

In this chapter details of materials, equipment and methods are presented.

4.1 MATERIALS AND SAMPLE PREPARATION

Fresh green bananas(Plantain) were collected from local market of Jadavpur, Kolkata, West Bengal. The peels were washed well with tap water to remove the dust and any impurities adhered to the outer surface. The peels were then cut into small pieces with a thickness of 2±0.1 mm and the remaining pulp portion was carefully removed using a peeler. The cut peels were blanched using at 85° C using KMS at 10% concentration.

4.2 DRYING TECHNIQUES OF BANANA PEEL

Different drying techniques are used to study drying kinetics.

4.2.1 *Freeze-drying (FD)*

At first, the fresh and processed banana peel slices were frozen at −40°C for 4 h in an ultra-low temperature freezer (C340-86, New Brunswick Scientific, England). Then FD was performed in a freeze dryer (FDU1200, Eyela, Japan) at a pressure of 14 Pa and a temperature of −45°C for 8 h (Altay et al., 2019; Saha et al., 2019)[41,43]

4.2.2 Microwave drying (MD)

A household microwave oven (CE1041DFB/XTL, Samsung, India)was used to perform the MD, and the working frequency was maintained at 2450 MHz and adjustable irradiation time and power levels. MD operated at five different power levels 800, 640, 480, 320, 160 W (Saha et al., 2019)[43].

4.2.3 Tray drying (TD)

Tray dryer (SS-24, Mac Pharma Tech, India) with 12 trays, and the dimensions of each tray were 0.75 × 0.35 m. During the whole drying process, the air velocity was maintained at 1.5 m/s, and the temperature was maintained at 60°C for drying (Altay et al., 2019)[41].

4.2.4 Vacuum drying (VD)

VD was carried out in a vacuum dryer (VS-1202 V5, ICT, India) at a temperature of 60°C and pressure of −760 mmHg (Monteiro et al., 2016)[45].

4.3 EXPERIMENTAL SET UP FOR DRYING

Once the dryers had reached steady-state conditions for the required points (at least 30 min), the samples were equally distributed in a 15 cm diameter circular glass tray and allowed to dry. The sample glass tray was positioned in the dryer's center. Using an analytical balance (TW-423, Shimadzu, Japan) with an accuracy of 0.1 mg, the weight of the banana peel, which was taken at a quantity of 10 gm, was measured. Moisture loss during the drying process was recorded at intervals of 22 minutes for tray drying, 27 minutes for freeze-drying, 15 minutes for vacuum drying, and 2 minutes and 30 seconds for microwave drying at power levels of 160, 320, 480, 640, and 800 W, respectively. When the Green banana peels' moisture loss was 88% (approximately), drying was stopped (wet basis).

After drying, the samples were kept in zip lock pouch at a desiccator until further processing and testing. To maintain the moisture content during the whole drying period, we used the desiccator. The initial and final moisture content was noted as 8.436 ± 1.543 g moisture/g dry matter (dm) and 1.063 ± 0.158 g moisture/g dm, respectively. The weight of the sample was taken as 10.024 ± 0.564 g. Changes in the moisture content were monitored after each time interval.

4.4 FORMULAS FOR DRYING KINETICS

The moisture ratio (MR) of the samples was determined by the drying kinetics, which were as follows (Saha et al., 2019)[43].

$$\mathbf{M_R = (M_t - M_e) / (M_0 - M_e)}$$

Where, M_t = is the moisture content at time t,

M_0 and M_e are initial and equilibrium moisture content.

All moisture contents were expressed in g moisture/g dm. The final moisture content was used as the as the equilibrium moisture content for each run.

The formula of measuring moisture content is:

$$M.C = (W\ wet\ sample - W\ dry\ sample) \times 100 / W\ dry\ sample.$$

Four thin layer drying models (Erbay & Icier, 2010) are widely used to explain the drying kinetics of banana peel(Table 1). This model has been taken from the general solution of Fick's law with some simplification and was established to improve the existing drying system or to control the drying process (Fan et al., 2015; Nadi & Tzempelikos, 2018).

For drying model selection, moisture ratios were fitted to 4 well known thin layer drying models which are generally applicable for drying of fruits and vegetables. The sum of square error (SSerror) were considered here as the primary criteria for selecting the best equation to describe the drying process. This provides the description how experimental values are deviated from the predicted values for a particular model. The coefficient of determination (R2) and SSerror were evaluated by application of the equations. (Altay et al., 2019; Saha et al., 2019) [43,44].

$$SS\ error = \sum(yi - \hat{y})^2$$

Where, ̂y represents for mean response and i-th observed response value is denoted as y_i.

Model Name	Model
LEWIS	MR = exp(− kt) [43]
HANDERSON PABIS	MR = a exp(− kt) [43]
LOGERITHIMIC	MR = a exp(− kt) + c [43]
WANG- SINGH	MR = 1+ at + bt² [43]

4.5 PROCESS OF FLOUR PREPARATION

The primary steps in the preparation of banana pee flour are generally washing, pre-treatment, drying, and size reduction. After all preparation, the banana peel slices are promptly dried, size-reduced, and sieved through sieves with a mesh size of 70.

4.6 EXTRACTION AND ASSAY OF ANTI-OXIDANT

4.6.1 *Extraction of samples*

Extracts of samples were prepared for the determination of antioxidant activity by weighing 1 g sample and mixed with 20 ml of 80 % methanol. Then mixture was sonicated for 10 min in a sonicator (Trans-O-Sonic/D150-IM, Mumbai) for reducing particle size. Then it was centrifuged (Hanil, Supra 22K, Korea) at 8944×g for 10 min at 4 °C. The extracts were transferred into glass tubes and were ready for use.

4.6.2 Antioxidant content and antioxidant activity

TOTAL PHENOLIC CONTENT (TPC)

The total phenolic content was determined according to the Folin Ciocalteu method [27]. Distilled water (1.8 ml) was added to 0.2 ml of extracted sample. Then, 0.2 ml Folin ciocalteu reagent was added and was mixed properly by shaking it manually for 5 min. Then, 2 ml of 7 % sodium carbonate solution was added. Next 0.8 ml distilled water was added. After incubation for 90 min in dark, the absorbance of the mixture was observed at 750 nm in a spectrophotometer [U2800, Hitachi, Japan]. Standard curve of total phenolic content was done by gallic acid. The results were expressed as mg of gallic acid equivalents (GAE) per g of dry weight of sample.

TOTAL FLAVONOID CONTENT (TPH)

Samples' total flavonoid content was calculated in accordance with Xu and Chang's recommendations [28]. 1 ml of the extracted material, 4 ml of distilled water, and 3 ml of $NaNO_2$ were combined. Then, 2 ml (1 M) NaOH and 0.3 ml $AlCl_3$ were added. The mixture's absorbance at 510 nm was then measured in the spectrophotometer after 25 minutes of light incubation. Catechins created a standard curve for the total flavonoid content. The outcome was given as mg of catechin equivalents (CAE) per g of sample dry weight . DPPH ,the free radical scavenging capacity of sample extracts was determined as stated by Yu et al. [29].

2,2-diphenyl-1-picrylhydrazyl radical (DPPH) 0.002 g was taken and was mixed with 50 ml of ethanol in a volumetric flask. Then the flask was kept in ice cold condition in the dark. Sample 0.1 ml was taken in a test tube and was mixed with 3.9 ml of prepared DPPH solution. Then, it was incubated in dark cabinet for 45 min and the absorbance was measured in a spectrophotometer at 515 nm.

$$\textbf{Total antioxidant activity} = [(\text{blank} - \text{sample})/\text{blank}] \times 100$$

4.7 NOODLES PREPARATION

4.7.1 Materials

Wheat flour which was passed through 100 mesh sieve, food grade sample of Guar gum , table salt was procured from local market of Jadavpur, Kolkata India and the banana peel powder which was prepared by tray drying followed by grinding and sieving.

4.7.2 METHODS OF PREPARATION

Banana peel powder at replacement levels of 10%, 20%, 25%, 35% was fortified in refined wheat flour. For preparation of white salted noodles, 100 g of refined wheat flour was mixed with water along with 2 g of table salt (sodium chloride), 2 gm of guar gum as a binding agent and mixed in a mixer for 2–6 min at medium speed. After mixing, the dough was sheeted in noodle making machine at 3 mm gap. The dough sheet obtained after sheeting was rested for 1 h and then the final sheets were cut into noodles strands (50 mm long and 2 mm wide). Finally, the product was steamed for 2 min and dried in a hot-air oven (UFB-400, Memmert, Germany) at 40 ± 1 °C up to 4 h . The product was cooled at ~ 40 °C and stored in plastic zip bags until further analyses. The composition of materials given in the table.

AMOUNT OF WHEAT FLOUR (gm)	AMOUBT OF GUAR GUM (gm)	AMOUNT OF BANANA PEEL POWDER (gm)	AMOUNT OF WATER (ml)	AMOUNT OF SALT (gm)
90	2	10	40	2
80	2	20	50	2
75	2	25	60	2
65	2	35	64	2

4.7.3 ANALYSIS OF COOKING QUALITY OF NOODLES

For further analyses 10 gm of noodles was taken for Water absorption test and were cooked in 400 ml of boiling water for 5 min and subsequently rinsed in cold water to prevent the overcooking of the noodles. Effect of banana peel powder addition at different percentage and effect of water added on cooking and sensory quality of noodles was studied.

Cooked noodles were analyzed for cooking characteristics such as cooking yield and cooking loss. Cooking yield and cooking loss of noodles were determined by method used by **Inglett et al.** with little modifications [25].

4.7.4 METHOD AND EVALUATION

10 grams of noodles were cooked in 400 ml of boiling distilled water in a 600 ml beaker for 5 min with little stirring. The beaker was covered with aluminum foil to

avoid evaporation losses. Cooked noodles were subsequently rinsed with cold water to prevent the overcooking of the noodles and then drained for 1 min before weighing of cooked noodles.

COOKING YIELD

Cooking yields of noodles were calculated from the difference between the noodle's weights before and after cooking. Because water absorbed during cooking resulted in weight gain of cooked noodles.

Cooking yield (%) = [(weight of cooked noodles − weight of dried noodles)/weight of dried noodles] × 100

COOKING LOSS

The remaining solution after cooking of noodles was transferred into a 600 ml volumetric flask and it was adjusted to volume with distilled water. 10 ml of the solution was pipetted into petri dish and dried to constant weight at 105 °C in hot air oven. The dried residue was weighed and the amount is reported as cooking loss.

Cooking loss (%) = (2) [weight of dried residue/weight of dry noodles before cooking] x 100

4.8 SENSORY EVALUATION OF NOODLES

Sensory properties of cooked noodles were evaluated by a semi trained sensory panel of ten members. They were technically familiar with the meaning of the descriptive terms used. Cooked noodles were used for evaluation of sensory parameters. Panelists were asked to evaluate color, appearance, mouth feel and texture. Overall acceptability of noodles was estimated by taking average of all the above sensory parameters. A nine-point hedonic scale (1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7=like moderately, 8=like very much and 9=like extremely) was used by the panelists to evaluate sensory attributes of cooked noodles.

RESULT AND DISCUSSION

In this chapter experimental results are presented in the form of figures and tables. An attempt has been made to explain the drying kinetics and the different parameters of prepared noodles from banana peel powder .

5.1 MOISTURE RATIO DATA

The moisture ratio data given in the tables numbering from 1 to 5. The tables depict the initial and final moisture content of Banana peel which undergoes different drying techniques at defined time intervals and also the moisture ratios consecutively. According to the values, moisture was completely eliminated during each drying operation, going from an initial moisture content of 8.540g moisture/g dm to a final moisture content of 0.880g moisture/g dm. According to extensive research, biological products almost fully dry during the period of declining rates. Similar to a prior study (Qiu & Chin, 2022; Sung et al., 2020), the drying of banana peel occurred in our study during the period of dropping rate.

5.2 DRYING KINETICS DATA

The moisture content data obtained by different drying techniques were converted to moisture ratio and was fitted to four thin-layer drying models which are presented in Table 1 to Table 8.

The models were evaluated on the basis SSerror . The drying model constants and coefficients from the results of statistical analysis of all models are given in Table 9. The Sum of square (SSerror) values varied from 2.58×10^{-4} to 10^{-3} .

Results showed that (Table 9) in Wang and Singh model, least SSerror values for all drying process were obtained and gave a better correlation between moisture ratio and drying time over the other models fitted (Figure 4 and Figure 5) and therefore is more precise to describe thin-layer drying of banana peel slices. Similar results were also reported by various researchers in semi-dried fruits [43], green chilies [44], red pepper [17], eggplant [45] and cassava [28].

The constants of Wang and Singh model (“a and “b”) were expressed in nonlinear form as a function of temperature. Hence new model was developed which represented moisture ratio (MR) as a function of temperature (T) and time (t).

The SSerror values shown in Table 9 specify good fitting of the model parameters.

5.3 ANTIOXIDANTS CONTENT AND ACTIVITY

Antioxidants include vitamins C and E, total flavonoid and total phenolic compounds. Total phenolic compounds are one of the most important groups of compounds occurring in plants which are interrelated with the antioxidant activity of the sample [39]. DPPH is a stable free radical compound and is widely used to test the free radical scavenging ability of various antioxidants [40].

In this study it is being attempt to show that the effect of different drying conditions on antioxidants property of dried banana peel. The data obtained from different drying techniques has given in Table10 . Peels dried by microwave at different power level show the highest antioxidant content in terms of TPC,TFC, DPPH.

From moisture content data table 1to 8 shows that the higher the microwave power applied the shorter time was required for drying the banana peels to constant weight.

Table 10 shows that different microwave drying conditions significantly affect TPC, TFC and also DPPH content in peel. The peels irradiated at 480W for 6 min were found to have the highest levels of TPC, TFC, DPPH respectively. As per the findings of our experiment it is being shown that as the microwave power increased from low (160W) to medium (480W), and then decreased at high power (640W and 800w) .

Our finding revealed that the dried banana peel shows that the stronger antioxidant activity could be obtained at power 480w(Table 5 and fig6), whereas, the samples dried at highest power 800w possessed the lowest activity. This result can be supported by Nguyen et al. (2015) [50] reported that the phenolic content of dried phyllanthus amarus increased with the microwave power from low (200w)to medium (400w)and then decreased at higher (600w). In case of other drying techniques, it also revealed that the lowest value of antioxidant. The differences between the present results in total phenolics, flavonoids, and free radical scavenging contents other investigators may be attributed to plant species, environmental condition and sample preparation beside the type of solvent. From table 5 it can also be inferred that if we make A comparison between the best condition of each drying method of banana peels on antioxidant recovery against other drying methods, we can conclude that the peels dried using microwave possessed the highest levels of phenolic content, flavonoids and DPPH followed by tray drying, vacuum drying and freeze drying. All investigators reported that the higher activity of DPPH radical scavenging activity may be attributed to the presence of higher levels of total phenolic content as they play a key role as proton donating ability and could serve as free radical inhibitors or scavengers, acting possibly as primary antioxidants.[40]

5.4 CHARACTERIZATION OF NOODLES FORTIFIED WITH BPP

5.4.1 WATER ABSORPTION CAPACITY

Flour water absorption capacity (WAC) principally determines its rheological attributes and the higher capacity is appreciated by food processors (Barbiroli et al. 2013)[52] Water absorption capacity of wheat flour increases with increasing percentage of addion of BPP in the composition(from 10% to 35%) (Table 11) Shows the data of water absorption capacity changing accordingly. The same results were observed by Eshak (2016)[51] in BPP supplemented flat bread. This might be due to higher amount of fiber in banana, which is considered a good water binder, so water absorption capacity of wheat flour was increased. Literature also suggests that fruits peel powder supplementation increases the flour water absorption capacity (Gunathilake & Abeyrathne 2008).[39]

5.4.2 COOKING YEILD

Cooking yield of noodles is a measure of water absorption during cooking process. A high value of cooking yield is generally considered good for explaining cooking quality of noodles. Effect of amount of addition of BPP and water level on cooking yield of cooked noodles is shown in Table11 Variation in water level used did not affect cooking yield of noodles supplemented with BPP. However, variations in BPP levels showed a significant effect on cooking yield. Cooking yield of noodles remained almost similar upto 10% BPP supplementation level. Further increase in BPP level the cooking yield increased sharply from 20% to 35%. This also can be explained as the water absorption capacity increases with increasing amount of BPP the cooking yield also increases. The cooking yield of noodles directly related with water absorption capacity which is directly influenced by the gluten protein content in noodles. The gluten protein in the noodles will denature and establish a bond during the heating process thus will preventing penetration of water at the gelatinization temperature (Kovacs et al., 2004) [15]. The increase in cooking yield with increasing amount of BPP was due to the no gluten protein content and also the addition of BPP disintegrates the gluten protein network that will facilitate the increased water absorption capacity is also due to the high amylose and dietary fiber in it which shows the high-water holding capacity.

5.4.3 COOKING LOSS

Cooking losses are important to assess the ability of the product to retain water during cooking and directly contribute to the final product yield. In this experiment, cooking losses for BPP incorporated flour noodles increased up to 13% which is shown in table11. The increase in cooking losses may be explained by lower amount of amylose starches in BPP that resulted in higher leaching (Lucisano et al. 2012). Noodles prepared with whole wheat flour showed lower cooking loss than BPP supplemented noodles. The result of cooking loss was due to the gluten protein network that was formed during the kneading with water as result of interaction between the gliadin and glutenin and also, the solid loss value was linked with bond formation between amylose and amylopectin. While weakening the amylose binding gluten network the whole structure of the noodles will get weaken and allow the solids leaching from the noodles at the time of cooking (Rayas-Duarte et al., 1996) [25].

A similar result of increasing cooking loss from 8.71 to 11.49 per cent was reported while increasing the banana flour due to the interaction of non-glutenous materials interaction with wheat protein(gluten) Ritthiruangdej et al. (2011) [26]. A study report by Hernandez-Nava et al. (2009) [56] explore that addition of unripe banana flour increases the solid loss also increased due to the high amylose content in banana flour, which will solubilize from noodles surface during cooking.

5.4.4 SENSORY EVALUATION

The sensory evaluation shows (TABLE12 to 15) that noodles prepared with 20% BPP were quite comparable and acceptable (**7.25)** in comparison with control (7.8) Table -16 Banana peel can be supplemented in noodles up to 15%, while high fibre proportion interferes with the flour matrix in a way to disintegrate the colour, texture, taste, and appearance score (table 12 to 16).

Higher fibre content leads to reduced score for texture (6.6), consequently reducing the overall acceptability (7.25) of noodles enriched with 20% BPP. Results for sensory attributes showed that score for noodles containing 20% BPP was maximum for taste (7.1). From the score of sensory data, it was clear that highest score for stickiness was obtained by the control sample. Texture, softness and color, which represent the feel of the product, were scored highest by control sample. The control noodles scored best for appearance. The overall acceptability scores differed a between the four samples with different composition with respect to addition of BPP. Similar results were reported by Eshak, (Eshak 2016)[51] for different types of flours. The BPP contains a higher amount of fructose, glucose, and proteins (Happi Emaga et al. 2007),[53] which makes it susceptible to Maillard's reaction during the powder production while existing oxidase enzymes also contribute to the enzymatic browning (Thipayarat 2007).[54] Therefore, the appearance of the banana peel supplemented noodles scored lower as compared to the control sample. Similarly, a lower taste score for BPP containing sample might be owing to the presence of tannins in peel which impart a bitter taste (Ehiowemwenguan & Inetianbor 2014).[55] The texture of the noodles decreased with BPP supplementation as it contains higher dietary fiber content.

Table: 1 Time Intervals-Moisture Ratio

MICROWAVE DRYING, POWER- 160, TIME INTERVAL= 152S			
SL NO.	**TIME INTERVALS**	**WEIGHT OF SAMPLE AT EVERY TIME INTERVAL**	**MOISTURE RATIO**
1	0	10.13	1
2	152	8.18	0.79
3	304	5.88	0.54
4	456	3.76	0.30
5	608	2.35	0.14
6	760	1.53	0.05
7	912	1.19	0.01
8	1064	1.10	0.00
9	1216	1.08	0.00
10	1368	1.06	0

Table: 2 Time Intervals-Moisture Ratio

MICROWAVE DRYING, POWER- 320, TIME INTERVAL= 64S			
SL NO.	**TIME INTERVALS**	**WEIGHT OF SAMPLE AT EVERY TIME INTERVAL**	**MOISTURE RATIO**
1	0	10.08	1
2	64	9.89	0.98
3	128	7.24	0.69
4	192	4.99	0.44
5	256	3.31	0.25
6	320	2.23	0.13
7	384	1.57	0.06
8	448	1.32	0.03
9	512	1.15	0.01
10	576	1.08	0

Table: 3 Time Intervals-Moisture Ratio

MICROWAVE DRYING, POWER- 480, TIME INTERVAL= 40S			
SL NO.	**TIME INTERVALS**	**WEIGHT OF SAMPLE AT EVERY TIME INTERVAL**	**MOISTURE RATIO**
1	0	10.14	1
2	40	9.09	0.90
3	80	6.85	0.65
4	120	4.96	0.43
5	160	3.42	0.26
6	200	2.37	0.15
7	240	1.72	0.07
8	280	1.35	0.03
9	320	1.10	0.00
10	360	1.06	0

Table: 4 Time Intervals-Moisture Ratio

MICROWAVE DRYING, POWER- 640, TIME INTERVAL= 50S			
SL NO.	TIME INTERVALS	WEIGHT OF SAMPLE AT EVERY TIME INTERVAL	MOISTURE RATIO
1	0	10.03	1
2	50	6.53	0.61
3	100	3.71	0.30
4	150	2.20	0.13
5	200	1.44	0.05
6	250	1.17	0.02
7	300	1.08	0.01
8	350	1.05	0.00
9	400	1.03	0.00
10	450	1.03	0

Table: 5 Time Intervals-Moisture Ratio

MICROWAVE DRYING, POWER- 800, TIME INTERVAL= 33S			
SL NO.	TIME INTERVALS	WEIGHT OF SAMPLE AT EVERY TIME INTERVAL	MOISTURE RATIO
1	0	10.07	1.00
2	33	7.60	0.73
3	66	4.77	0.41
4	99	2.77	0.19
5	132	1.79	0.08
6	165	1.31	0.03
7	198	1.12	0.01
8	231	1.08	0.00
9	264	1.07	0.00
10	297	1.06	0.00

Table:6 Time Intervals-Moisture Ratio

VACCUM DRYING, TIME INTERVAL= 15 MIN			
SL NO.	TIME INTERVALS	WEIGHT OF SAMPLE AT EVERY TIME INTERVAL	MOISTURE RATIO
1	0	10.04	1
2	15	9.24	0.91
3	30	8.24	0.78
4	45	7.63	0.73
5	60	6.29	0.58
6	75	4.95	0.44
7	90	3.60	0.29
8	105	2.74	0.19
9	120	1.38	0.04
10	135	1.03	0

Table: 7 Time Intervals-Moisture Ratio

TRAY DRYING, TIME INTERVAL= 22 MIN			
SL NO.	TIME INTERVALS	WEIGHT OF SAMPLE AT EVERY TIME INTERVAL	MOISTURE RATIO
1	0	10.16	1.00
2	22	8.44	0.81
3	44	6.13	0.56
4	66	5.79	0.52
5	88	4.95	0.43
6	110	3.84	0.30
7	132	2.33	0.14
8	154	1.84	0.08
9	176	1.21	0.01
10	220	1.08	0

Table: 8 Time Intervals-Moisture Ratio

FREEZE DRYING, TIME INTERVAL= 27 MIN			
SL NO.	TIME INTERVALS	WEIGHT OF SAMPLE AT EVERY TIME INTERVAL	MOISTURE RATIO
1	0	10.13	1
2	27	5.17	0.45
3	54	4.03	0.34
4	81	2.17	0.12
5	108	1.65	0.07
6	135	1.14	0.04
7	162	1.12	0.01
8	189	1.11	0.01
9	216	1.09	0.00
10	243	1.06	0

Table: 9 Drying Kinetics Model of different drying process using R software

Process	Lewis model	
	k	*SSE*
TD	0.01	0.04
FD	0.02	0.01
VD	0.12	0.10
MD160	0.16	0.04
MD320	0.28	0.12
MD480	0.37	0.06
MD640	0.55	0.15
MD800	1.00	0.03

	Henderson Pabis model		
	K	*a*	*SSE*
TD	0.01	1.04	0.04
FD	0.02	0.99	0.01
VD	0.01	1.10	0.08
MD160	0.17	1.07	0.04
MD320	0.32	1.14	0.09
MD480	0.41	1.10	0.05

MD640	0.94	1.92	0.01
MD800	1.04	1.05	0.02

	Logarithmic model			
	K	*a*	*c*	*SSE*
TD	0.01	1.57	-0.59	0.01
FD	0.02	0.99	0.00	0.01
VD	0.00	14.67	-13.96	0.71
MD160	0.00	0.64	0.06	2.34
MD320	0.00	0.89	-0.19	2.06
MD480	0.00	0.95	-0.25	1.99
MD640	0.84	1.85	-0.04	0.00
MD800	0.83	1.14	-0.10	0.01
	Wang and Singh model			
	Intercept	*Th*	*Th^2*	*SSE*
TD	0.98	-0.01	0.00	0.01
FD	0.88	-0.01	0.00	0.05
VD	1.00	-0.01	0.00	0.00
MD160	1.03	-0.12	0.00	0.01
MD320	1.11	-0.25	0.01	0.04
MD480	1.06	-0.30	0.02	0.01
MD640	1.37	-0.66	0.08	0.01
MD800	1.01	-0.71	0.12	0.01

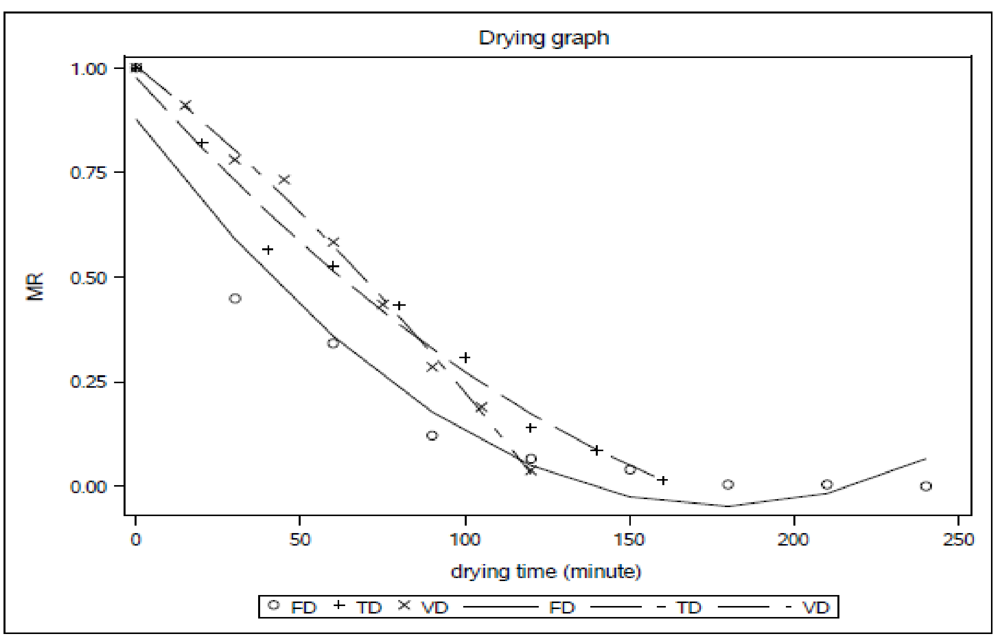

Fig.4: Drying Kinetic Modeling Curve for Tray (TD), Vaccum(VD), Freeze(FD) Drying

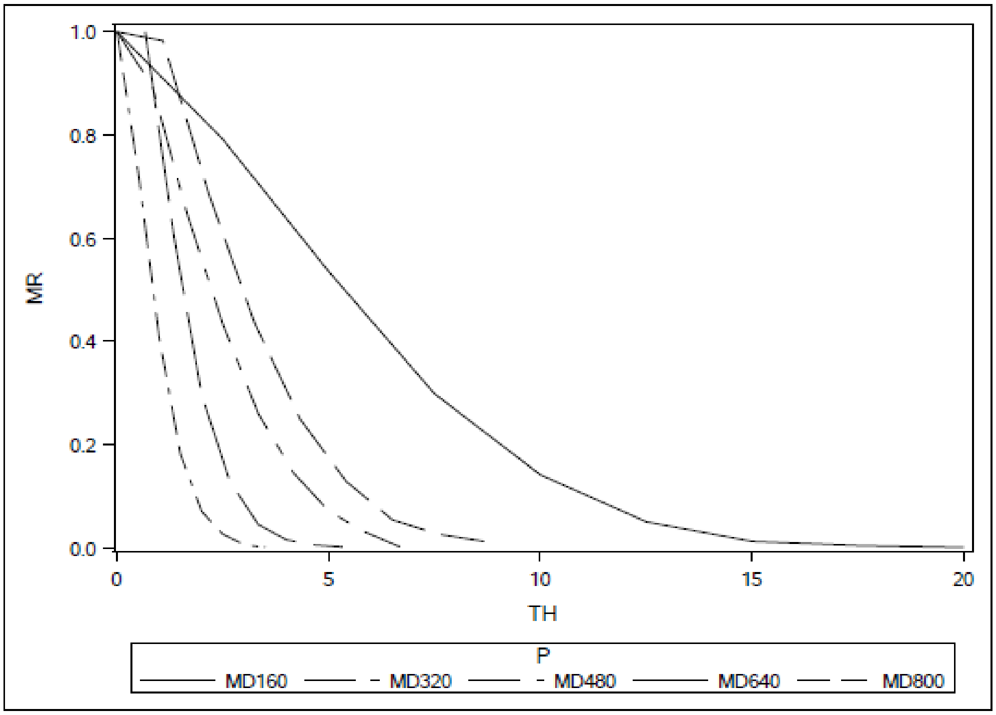

Fig.5: Drying Kinetic Modeling Curve for Microwave (MD) Drying at 160W, 320W, 480W, 640W and 800W

Table: 10 Anti-Oxidant Data

PROCESS	PARAMETERS VALUE		
	TPC	TFC	DPPH
FRESH	1.74±0.037	2.05±0.043	26.88±0.564
MWD 800	5.77±0.121	3.52±0.074	46.16±0.969
MDW 640	5.92±0.124	3.55±0.075	47.36±0.995
MDW 480	6.78±0.142	4.52±0.096	56.64±1.189
MDW 320	6.61±0.139	4.41±0.092	54.88±1.152
MDW 160	6.11±0.128	3.86±0.081	48.68±1.022
TD	6.13±0.129	3.68±0.77	49.04±1.030
VD	2.79±0.059	2.26±0.047	22.32±0.469

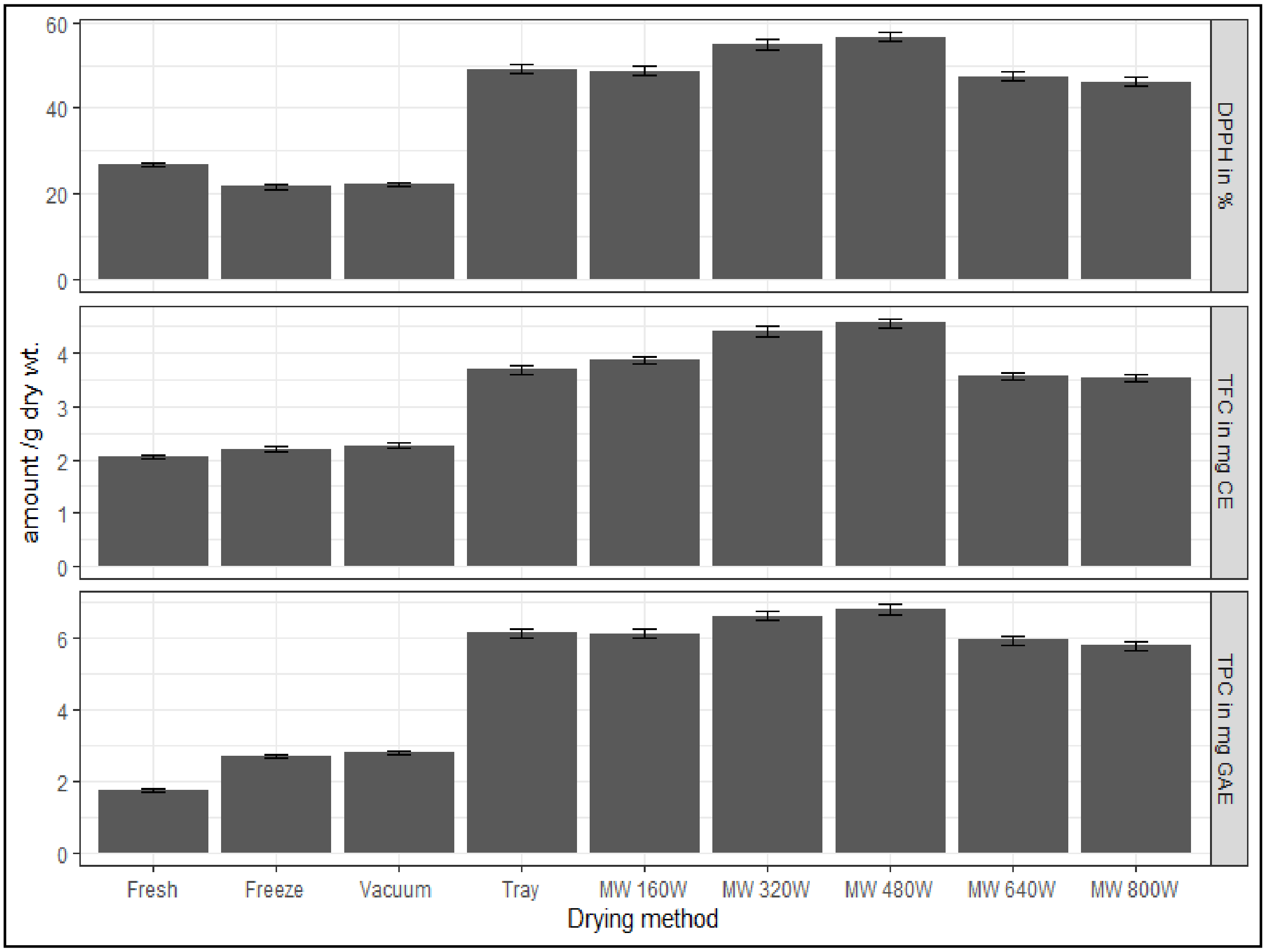

Fig.6: Anti-Oxidant Contents of TPC, TFC, DPPH at different drying process

Table: 11 Analytical Data of Noodles

COMPOSITION OF FLOURS (WHEAT FLOUR:BPP)	WATER ABSORPTION CAPACITY (%)	COOKING YIELD (%)	COOKING LOSS (%)
90:10	12.15	32.80	5.10
80:20	42.15	84.12	12.30
75:25	62.14	157.16	15.60
65:35	91.50	230.70	17.40
Control	85.20	147.60	4.38

Table:12: Sensory Evaluation for Noodles at different composition of Wheat Flour and Banana Peel Powder (BPP)

SAMPLE COMPOSITION- FLOUR: BPP = 90:10					
PARAMETERS	**COLOR**	**APPEARANCE**	**MOUTHFEEL**	**TEXTURE**	**OVERALL ACCEPTABILITY**
1	6	5	4	4	4.9
2	5	5	4	4	
3	6	6	4	4	
4	6	6	5	4	
5	5	7	5	4	
6	7	5	5	5	
7	5	5	3	5	
8	6	6	3	4	
9	6	5	4	4	
10	6	5	4	4	
	5.8	5.5	4.1	4.2	

Table:13: Sensory Evaluation for Noodles at different composition of Wheat Flour and Banana Peel Powder (BPP)

SAMPLE COMPOSITION- FLOUR: BPP = 80:20					
PARAMETERS	**COLOR**	**APPEARANCE**	**MOUTHFEEL**	**TEXTURE**	**OVERALL ACCEPTABILITY**
1	8	8	5	7	
2	7	9	6	7	
3	7	8	7	7	
4	7	9	6	8	
5	8	7	7	6	
6	8	7	7	7	7.25
7	5	8	6	6	
8	7	8	7	7	
9	8	8	8	8	
10	8	8	7	8	
	7.3	8	6.6	7.1	

Table:14: Sensory Evaluation for Noodles at different composition of Wheat Flour and Banana Peel Powder (BPP)

SAMPLE COMPOSITION- FLOUR: BPP = 75:25					
PARAMETERS	**COLOR**	**APPEARANCE**	**MOUTHFEEL**	**TEXTURE**	**OVERALL ACCEPTABILITY**
1	6	6	5	6	
2	7	6	6	6	
3	6	5	6	6	
4	6	6	6	6	
5	6	6	6	5	
6	6	6	5	5	5.9
7	7	6	6	5	
8	6	6	6	6	
9	6	7	6	6	
10	5	6	6	6	
	6.1	6	5.8	5.7	

Table:15: Sensory Evaluation for Noodles at different composition of Wheat Flour and Banana Peel Powder (BPP)

SAMPLE COMPOSITION- FLOUR: BPP = 65:35					
PARAMETERS	**COLOR**	**APPEARANCE**	**MOUTHFEEL**	**TEXTURE**	**OVERALL ACCEPTABILITY**
1	4	4	3	3	3.98
2	4	5	3	4	
3	5	4	4	4	
4	4	3	4	5	
5	4	4	4	4	
6	4	5	3	3	
7	5	4	4	4	
8	4	4	3	5	
9	5	3	4	4	
10	4	4	5	3	
	4.3	4	3.7	3.9	

Table:16: Sensory Evaluation for Noodles at control

SAMPLE COMPOSITION- FLOUR- 100% CONTROL					
PARAMETERS	**COLOR**	**APPEARANCE**	**MOUTHFEEL**	**TEXTURE**	**OVERALL ACCEPTABILITY**
1	8	8	7	8	
2	7	8	7	7	
3	7	8	7	8	
4	7	8	7	8	
5	9	7	8	9	
6	8	7	8	9	7.8
7	8	9	8	8	
8	7	9	8	8	
9	8	9	7	7	
10	8	9	7	7	
	7.7	8.2	7.4	7.9	

SUMMARY AND CONCLUSION

6.1 SUMMARY

The study was conducted on thin layer banana peel to find the kinetics of drying and ultrasound-assisted extraction process of antioxidant contents under different drying processes. Wang & Singh model was found the best-fitted drying model with a low SSerror [0.0035 – 0.05] value. The microwave dried banana peel at the power level 480w had a high content of total phenolics of 78.364 mg/g, flavonoids of 10.819 mg/g (dm) content, DPPH of 74.621 µmol/g, antioxidant content, but quality parameters are best for a freeze-drying product.

In this study, to develop a value-added product with banana peel we substituted wheat flour with banana peel powder (BPP) at supplementation rates of 10,20,25 and 35%, and evaluated their suitability to develop noodles. The results showed that water absorption capacity, cooking yield and cooking losses were increased with BPP incorporation in WF.

Furthermore, results for sensory evaluation demonstrated that noodles with 20% BPP scored highest in terms of overall acceptability.

6.2 CONCLUSION

The following conclusion may be draw from the present study.

- Green banana peel is a low cost versatile product with high nutrition value along with antioxidants content in terms of phenolic and flavonoid content which has the potential to be transformed into functional foods because it is historically consumed as food and medicine in some regions of the world.

- According to the experimental results, the Wang and Singh model has adjudged the best thin layer drying model for analyzing the drying kinetics of the Banana peel. The model has the lowest SSerror value among all four models studied.

- Along with measuring the optimum drying condition this also helps to satisfy advanced manufacturing processes which include statistical processing for proper completion of the drying process.

- It will also favorably support as an informational tool in the design and simulation of drying.

- It can also be concluded that fortification with banana peel gives the value added product like noodle in which the wheat flour incorporated with 20% banana peel powder shows its maximum acceptability with high dietary fibre.

- It can also be inferred that with water absorption capacity cooking yield increases which impart an explanation about the starch content and protein interaction during heat treatment.

1) Under static condition rolling friction is predominating due to increase density at higher energy level in a similar way, cohesion is predominant at lower energy level.

2) The variation of resilient modulus with no of cycles is erratic up to 50-100 cycles beyond which it almost reaches constant values.

3) With the higher confining pressure, the resilient modulus is higher at same deviator stress under same confining pressure, the resilient modulus decreases with the increasing deviator stress to reach at failures.

4) Under same confining pressure and with same deviator stress, the resilient modulus decreases with moisture content of the soil resulting in an increasing in resilient modulus.

6.3 SCOPE OF FURTHER RESEARCHES:

The further research work may be conducted in the following areas

1) Research work may be done on optimization of best drying method by calculating the molecular diffusivity.
2) An attempt has also been made to find out a co-relation between different process variables of noodles fortified with banana peel powder like amount of water, mixing time, cooking yield and cooking loss.


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