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Research Article

Impact of Slice Thickness and Baking Temperature on the Physicochemical Quality and Nutritional Properties of Newly Developed Baked Coconut Chips

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Due to rising health concerns, consumers are increasingly inclined toward reduced-fat products, which have driven the need for nutritious alternatives through modifications in recipes and production processes. Despite the growing popularity of coconut-based products, there is limited research on baked coconut chips, particularly regarding the effects of baking temperatures and product thicknesses. This study addresses this gap by developing baked coconut chips samples (BCSs) as a healthier alternative to traditional fried chips. Baking experiments were conducted at temperatures of 140°C, 160°C, and 180°C, with 160°C identified as optimal for balancing processing time and product quality. The study also compared baked coconut chips with those that were dried and then baked (dried baked coconut chips samples [DBCS]). Among the trials, the 0.5-mm-thick coconut chips baked at 160°C exhibited favorable sensory attributes and notable biochemical properties, including 3.13% moisture content, 1.13% ash, 40.49% fat, and significant antioxidant activity.

Keywords: biochemical properties; coconut chips; dry heat; moisture content; total phenolic content

1. Introduction

Coconut palms, scientifically known as *Cocos nucifera* L., are frequently referred to as "trees of life" or "trees of abundance" and have immense economic importance in tropical areas because every element of the palm fulfills a useful purpose [1]. Coconuts are a primary source of income in India for more than 10 million people. Coconuts are primarily grown in the southern states of India [2]. Beyond their fresh consumption, coconuts are a vital raw material for various products, including coconut oil, milk, and cream. Additionally, they are processed into desiccated coconut powder, flakes, chips, flavored coconut milk, prebiotic drinks, and virgin coconut oil [3]. In traditional practices, both the fresh coconut kernel and the dried form, known as copra, serve as primary sources for extracting coconut milk and coconut oil, respectively [4]. The coconut kernel is rich in amino acids, minerals, and antioxidants, such as phenolics and tocopherols. The main consumable component of the coconut, known as the kernel, is widely employed for extracting oil, coconut milk, and cream. Moreover, it is extensively used in both bakery and culinary applications [5]. The coconut kernel plays a crucial role in snack food production due to its versatile applications and nutritional benefits. It can be used in various forms, such as shredded, desiccated, or coconut flour, providing flexibility in the production of snack foods.

In the present context, quick and convenient snacks have become an essential aspect of everyday living worldwide [6]. Snack food serves as a convenient, pleasant, and sometimes nutritious component of the modern diet, catering to the diverse needs and preferences of consumers around the world [7]. However, making mindful choices and balancing indulgent snacks with healthier options is essential to support overall health and well-being. Snack foods are produced using various ingredients, and many studies were conducted to improve their nutritional properties. Giuffrè et al. [8] conducted a study comparing breadsticks seasoned with onions and olives, made using olive pomace oil or extra virgin olive oil. Breadsticks made with extra virgin olive oil exhibited superior physical, chemical, and sensory characteristics during each sampling period. Mireault et al. [9] examined the food and nutrient intake from snacks consumed by children aged 3–5 years, both in regulated child care (RCC) and at home. At RCC facilities, a significantly wider range of food categories and snacks with higher sodium and fiber contents were consumed compared to those at home. Moreover, morning snacks at home contained significantly more sugar than those at RCC.

In that context, coconut chips are a versatile snack that can be enjoyed on their own as a tasty treat or used as a topping for yogurt, salads, or baked goods [10]. Coconut chips provide a convenient way to incorporate the tropical flavor of coconut into our diet while reaping the nutritional benefits they offer. There is a great popularity and consumption of fried chips in Southeast Asian countries. In addition, chips are known to contain high levels of the acrylamide precursor [11]. Daniali et al. [12] reported that banana chips may undergo significant acrylamide formation due to the generation of intense heat during processes such as deep-fat frying and the abundance of acrylamide precursors. The reduction in the acrylamide content in banana chips is a significant research priority. Baking plays a crucial role in creating exceptional baked goods. During baking, heat and mass transfer occur simultaneously, resulting in a quick elevation of the core temperature and the formation of a dry surface crust. The existing method for producing coconut chips using a hot air dryer is time-consuming, requiring 6 h at 65°C as described by Pravitha et al. [13]. Therefore, this study introduced a quick and easy method for producing coconut chips to address this research gap.

Factors such as oven temperature, baking duration, and humidity levels significantly impact the development of all quality characteristics during the baking process [14]. The process requires elevated temperatures, typically ranging from 160°C to 250°C [15]. During baking, the product undergoes various physical and chemical changes, including water evaporation, the formation of crust and crumb structures, the expansion of the volume, denaturing proteins, and gelatinizing starch [16]. To enhance the quality of the final product, it is essential to understand the baking process thoroughly, taking into account both transport phenomena and structural modifications [17].

Abd El-Baset and Almoselhy [18] observed that baking biscuits at 180°C resulted in biscuits with a high moisture content and reduced consumer satisfaction while baking at 220°C led to the formation of acrylamide levels exceeding the limit of the safety standards set for children's biscuits. Hence, it was concluded that baking biscuits at 200°C for 20 min achieved optimal quality attributes, safety, and consumer acceptance.

However, there is no documentation or research on the baking of coconut kernels to produce coconut chips. Therefore, this study aimed to assess the physicochemical quality of coconut chips baked at various temperatures and to determine the ideal baking conditions that yield the finest product characteristics and consumer satisfaction.

2. Materials and Methods

2.1. Materials. Coconut samples of the West Coast Tall (WCT) variety of 10 months old maturity were collected from instructional farm of ICAR Central Plantation Crops Research Institute (ICAR–CPCRI) in Kasaragod, India. Table sugar was purchased locally in Kasaragod, Kerala, while sodium chloride (NaCl) and concentrated vanilla essence were acquired from International Flavors and Fragrances Private Limited in Chennai, Tamil Nadu.

2.2. Methods

2.2.1. Preparation and Processing of the Sample. The initial phase of sample preparation involved the removal of the coconut husk. The dehusker, having a 2-horsepower engine, processed 350 coconuts per hour. Subsequently, the dehusked coconut underwent deshelling and testa removal procedures using machineries developed at the ICAR–CPCRI. Following this, the coconut kernel underwent slicing with the CPCRI slicer (Patent Number: 285418), providing thickness options of 0.5 mm and 1.4 mm for the produced slices. Once sliced, coconut kernels were blanched in hot water for 2 min at temperatures ranging from 90°C to 95°C. After blanching, the sliced coconut kernels were subjected to osmotic dehydration.

The osmotic solution, of 45° Brix, comprises 1 kg of table sugar, 20 g of salt, and 20 mL of vanilla essence for flavoring, dissolved in 1 L of water [19]. To achieve the desired sweetness and texture parameters, coconut chips were soaked in an osmotic solution for 45 min [20]. The osmotically dehydrated slices were baked in an oven at temperatures of 140°C, 160°C, and 180°C.

2.3. Baking. Baking is a method of preparing food that uses dry heat, typically in an oven by transfer from the surface to the center. Baking was done in an oven (Italiya—Food Machinery [Italy], semiautomatic stainless steel two-tray single-deck gas oven, mode: ABEDO-2TG, 13 kg capacity, 0.1 kw/h power requirement). An optimized baking procedure is an effective method for reducing acrylamide levels. Higher baking temperature and more duration lead to the formation of acrylamide and browning reactions [21]. The baking of 500 g of chips samples was performed on a single tray at different temperatures (140°C, 160°C, and 180°C) and baked until the desired crispiness and quality attributes were reached. Increasing temperature reduces the baking time, with the untreated chips requiring more time to bake (baked coconut chips samples [BCS]—15–35 min) compared to the dried and then BCS (dried baked coconut chips samples [DBCS]—2–7.5 min).

Coconut chips were also produced through a combined process involving drying (hot air drying at 65°C for 6 h) followed by baking, conducted at varying temperatures (140°C, 160°C, and 180°C); these baking temperatures were chosen based on a previous study [22], and the quality of the final product was evaluated (Figure 1). The osmobaked/osmodried samples are packed in aluminum foil laminated with LDPE film pouches until further use.

2.4. Physical Analysis

2.4.1. Rehydration Ratio and Hygroscopicity. The evaluation of the rehydration ratio in coconut chips followed the methodology outlined by Zou et al. [23] with slight modifications. Briefly, 5 g of prepared chips samples (DBCS and BCS) underwent rehydration in 250 mL of water over 3 h. Following the rehydration phase, the samples were extracted, and any excess surface water on the coconut chips was absorbed using filter paper before measuring the sample's weight. The hygroscopic properties of coconut chips samples (DBCSs and BCSs) were utilized to characterize moisture absorption behavior [24]. Five grams of coconut chips was weighed and placed in a sealed desiccator under controlled conditions: 25°C temperature and 75.2% humidity. The desiccator contained a saturated NaCl solution placed in an incubator to maintain these conditions. After 1 week, the chips were reweighed, and the results were expressed as the amount of water gained per 100 g of dry matter,

$$\text{Reydration ratio (RR)} = \frac{\text{Mr}}{\text{Md}}, \quad (1)$$

where Mr is the mass of the rehydrated chips (g) and Md is the mass of the chips before rehydration (g).

2.5. Biochemical Analysis

2.5.1. Determination of the Proximate Composition. The appropriate AOAC (2005) methods were employed to determine the proximate composition of coconut chips produced through the baking process. The hot air oven method, as per AOAC 925.09, 2005, was utilized to assess the moisture content. For the estimation of the ash content, the sample was analyzed following the procedures outlined in AOAC 938.08, 2005. The total carbohydrate content was determined using the phenol sulfuric acid method. The micro-Kjeldahl method (AOAC 955.04) was employed for protein content estimation, while the fat content was determined through the Soxhlet method (AOAC 920.58).

2.5.2. Determination of the Total Phenolic Content (TPC). The determination of the TPC employed a spectrophotometric method using Folin–Ciocalteu (FC) reagent, following the approach outlined by Seneviratne and Kotuwegedara [25] with slight modifications. In this process, 1 mL of the ethanol-extracted sample solution was pipetted into test tubes. A series of test tubes received 0.1, 0.2, 0.3, 0.4,

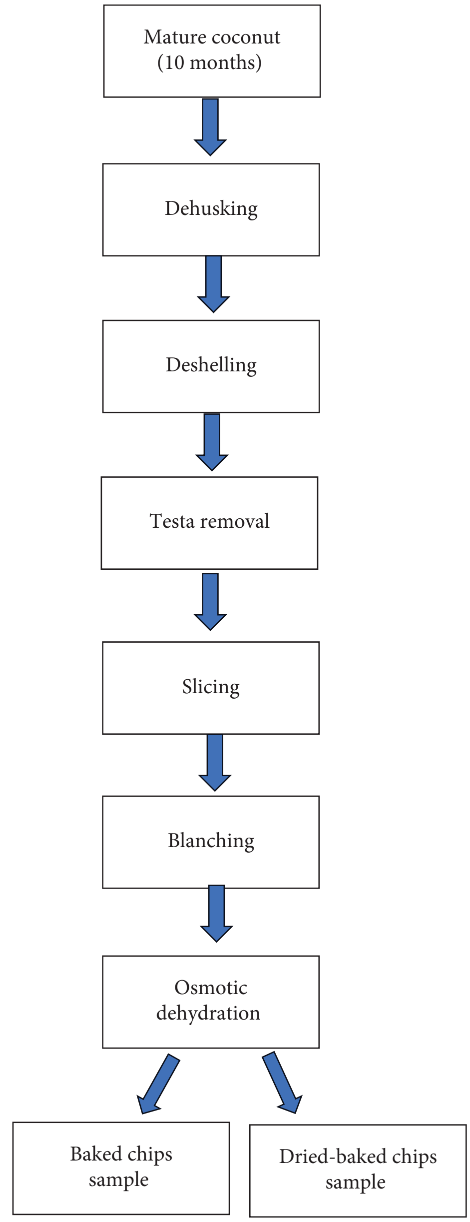

Figure 1: Process flowchart for the preparation of baked coconut chips.

and 0.5 mL of the working standard solution. Both samples and standards were duplicated, and the volume was adjusted to 3 mL with distilled water. Separate test tubes were filled with 3 mL of distilled water to serve as blanks. Subsequently, 0.2 mL of 1M Folin–Ciocalteu reagent was added, followed by 2 mL of 7% Na_2CO_3 solution, and the mixture was incubated for 45 min in the dark. The absorbance was recorded at 745 nm. This analytical procedure was replicated, and the TPC was expressed as milligrams of gallic acid equivalent per gram of sample (mg GAE/100 g).

2.5.3. Determination of Antioxidant Potential by ferric reducing antioxidant power (FRAP) and 2,2-Diphenylpicrylhydrazyl (DPPH) Methods. The FRAP assay was executed in accordance with the protocol delineated by

Benzie & Strain, [26]. Exactly, 0.5 mL of extract was taken in test tubes. Blank and standard were also prepared using water and Trolox working standards. Two mL FRAP reagent was added to all the tubes and made up to 10 mL with distilled water. The tubes were incubated for 20 min at room temperature, and the absorbance was read at 593 nm.

The DPPH assay was conducted following the methodology described by Brand-Williams et al. [27]. The ethanol-extracted sample (0.5 mL) was taken in a test tube and made up to 2 mL using ethanol. Two mL of ethanol served as a blank. Then, 750 μL of DPPH solution was added to the sample and blank and incubated for 15 min under dark conditions. The absorbance of the solutions was noted at 510 nm (UV–visible, Model Shimadzu, UV-160A, Japan). The results of the FRAP and DPPH assays were presented as mg Trolox equivalent (mg TE)/100 g and as a percentage, respectively.

2.6. Sensory Analysis. Sensory attributes of coconut chips were assessed by 10 trained persons (five male and five female including the age group of 25–60 years). Appearance, crispiness, flavor, color, and overall acceptability were analyzed during the sensory study. A brief description of the product was given to the members before analysis. Coconut chips were kept in dishes with unique numbers for identification. Drinking water was also provided to clear the mouth before assessing the next sample. The panel assigned scores on the nine-point hedonic scale, and the response was recorded [28].

2.7. Statistical Analysis. Each experiment was conducted with three replicates, and all parameters were reported as the average value ± standard deviation (SD). The effect of different baking temperatures and slice thickness was analyzed using a two-factorial and completely randomized design, employing ICAR's statistical analysis tool, Web Agri Stat Package 2.0 [29].

3. Results and Discussion

3.1. Effect of Processing Parameters on the Rehydration Ratio of BCSs and DBCSs. As shown in Table 1, different baking temperatures significantly affected the rehydration ratio ($p < 0.05$). The rehydration ratio is an important quality parameter of dried products. It refers to the capacity of dehydrated products to absorb water without breaking down or disintegrating [30]. The rehydration ratio of the final product is significantly influenced by the physical and chemical changes brought about by the dehydration process [31].

It was observed that as the baking temperature increased, the rehydration ratio decreased. The rehydration ratio of BCSs of thickness 0.5 mm at 140°C was found to be the highest (1.77%). Among the thicknesses of 1.4 mm, the highest value of the rehydration ratio (1.69%) was found in the baked samples at 140°C. This could be attributed to the adverse impact of temperature, which led to the caramelization of sugar, consequently causing pores on the surface to clog. This results in reduced water diffusion through the surface during the rehydration process [32]. Singh et al. [32] also found similar results of a decreased rehydration ratio for water chestnut as the air temperature in the cabinet oven increased. In the case of DBCS of both thicknesses, the highest rehydration ratio was observed at 160°C. It was observed that the drying method and temperature influence the rehydration ratio. Seremet (Ceclu) et al. [31] studied that hot air pumpkin slices have a higher rehydration ratio than other combined techniques such as hot air convection at 60°C followed by hot air ventilation at 40°C simultaneously with microwave treatment. The thickness of the sample is also a crucial factor influencing the rehydration ratio. A sample thickness of 0.5 mm was observed to have a relatively higher rehydration ratio than the 1.4-mm sample.

3.2. Effect of Processing Parameters on the Hygroscopicity of BCSs and DBCSs. The hygroscopicity of dried food products affects their crispiness by absorbing water molecules from the surrounding air [33]. When foods are dried, their water content is significantly reduced, making them more prone to absorbing moisture when exposed to humid conditions. The different baking temperature was observed to significantly affect the hygroscopicity of the coconut chips samples ($p < 0.05$).

Coconut chips produced at higher baking temperatures were found to be more hygroscopic. The sample (0.5 mm) baked at 180°C was found to have a higher hygroscopicity value (7.41%) than those at a lower temperature of 140°C (3.45%). Dried baked chips samples also exhibited higher hygroscopicity values when exposed to elevated temperatures. The increased baking temperature reduces the moisture content of the coconut chips sample and increases the porosity of the food, making it more hygroscopic and prone to absorbing moisture [34]. These findings are consistent with those reported by previous studies [24] that investigated the influence of the spray drying process conditions on the acai powder. They observed the lowest hygroscopicity values with decreasing temperature. Ferreira and Pena [35] observed a similar trend and proposed that the temperature rise induces alterations in the physical structure of the product. This, in turn, reveals a greater number of active sites that have an affinity for water molecules.

3.3. Effect of Processing Parameters on Moisture Content of BCSs and DBCSs. The moisture content is an important parameter that determines the quality of dried products. Osmotic dehydration leads to a decrease in the moisture content of coconut chips samples. Different baking temperatures significantly affected the moisture content of the coconut chips samples ($p < 0.05$). The baking time observed for prepared coconut chips of different baking temperatures at 140°C, 160°C, and 180°C was 35, 25, and 15 min, respectively. At 140°C, the highest moisture content was observed for both baked chips and dried baked chips samples at both thicknesses. Those dried at a higher temperature of 180°C were observed at the lowest moisture content. It has been observed that raising the baking temperature can accelerate the rate of water loss during baking [36].

Table 1: Physical properties of baked and dried baked coconut chips samples.

Treatment	Sample ID	Physical properties			
		0.5 mm		1.4 mm	
		Rehydration ratio (%)	Hygroscopicity (%)	Rehydration ratio (%)	Hygroscopicity (%)
T1	BCS-180°C (15 min)	1.58 ± 0.06^{ef}	7.41 ± 0.46^{a}	1.57 ± 0.03^{c}	4.98 ± 0.02^{b}
T2	BCS-160°C (25 min)	1.71 ± 0.00^{d}	4.34 ± 0.09^{d}	1.65 ± 0.00^{b}	3.45 ± 0.17^{a}
T3	BCS-140°C (35 min)	1.77 ± 0.00^{bcd}	3.45 ± 0.17^{c}	1.69 ± 0.00^{ab}	3.27 ± 1.67^{cd}
T4	DBCS-180°C (2 min)	1.61 ± 0.02^{e}	5.40 ± 0.24^{b}	1.49 ± 0.01^{de}	3.93 ± 0.16^{bc}
T5	DBCS-160°C (5 min)	1.81 ± 0.00^{bc}	4.33 ± 0.12^{c}	1.76 ± 0.00^{a}	2.53 ± 0.17^{def}
T6	DBCS-140°C (7.5 min)	1.76 ± 0.00^{cd}	2.09 ± 0.11^{e}	1.56 ± 0.03^{cd}	2.02 ± 0.12^{def}

Note: The different letters in the columns indicate a significant effect at a level of 0.05.
Abbreviations: BCS, baked chips sample; DBCS, dried-baked chips sample.

In baking, dry heat transferred from the surface to the center that evaporates the moisture in the product. McFarlane [37] studied the concept of injecting heat during baking taking advantage of the high latent heat of evaporation of water.

3.4. Effect of Processing Parameters on Total Ash Content of BCSs and DBCSs. "Ashing" refers to the process of burning a food sample at a high temperature to remove all organic material, leaving behind only the inorganic mineral content, also known as ash [38]. There was a significant difference in the ash content between the coconut chips samples when baked at different temperatures ($p < 0.05$). Samples with thicknesses of 0.5 mm and 1.4 mm, when baked at 160°C, exhibited a higher retention of ash content (1.13% and 0.86%, respectively) (Table 2). At a lower temperature of 140°C, both thicknesses showed a relatively reduced ash content (0.87% for 0.5 mm thicknesses and 0.54% for 1.4 mm thicknesses).

The effect of the baking temperature on the ash content of the food material involves a balance between the efficiency of moisture removal and the preservation of food quality and composition. Baking at higher temperatures can lead to more efficient moisture removal from the food material. However, excessively high temperatures can also lead to chemical changes in food components, including the potential degradation or loss of certain heat-sensitive nutrients and compounds. Miranda et al. [39] noted a comparable outcome wherein the ash content of aloe vera gel increased with increasing drying temperatures up to a specific threshold, beyond which it began to decrease. There may be an optimal temperature range for drying that balances the need for efficient moisture removal with the preservation of the food's nutritional and chemical composition.

3.5. Effect of Processing Parameters on the Total Carbohydrate Content of BCSs and DBCSs. Foods contain carbohydrates as a main source of energy, impart important textural properties, and provide dietary fiber [40]. The effect of different baking temperatures on the total carbohydrate content of the chips sample is given in Table 2. There were three different baking temperatures, and there was a significant difference ($p < 0.05$) among them.

Baked chips showed higher carbohydrate retention at lower temperatures (140°C). For example, a carbohydrate content of 34.35 glucose eq/100 g was observed for chips with a thickness of 0.5 mm and 29.25 glucose eq/100 g for chips with a thickness of 1.4 mm. On the contrary, increased temperature (180°C) resulted in greater carbohydrate degradation, with values dropping to 25.72 glucose eq/100g for 0.5-mm chips and 23.06 glucose eq/100g for 1.4-mm chips. The degradation may be due to the Maillard reaction. This reaction occurs between reducing sugars (such as glucose or fructose) and amino acids (from proteins) when heated at high temperatures. It leads to the browning of food and the formation of flavorful compounds. Although this reaction can enhance the taste and aroma of baked goods, it can also result in the breakdown of carbohydrates, particularly if the baking temperature is too high or the baking time is too long [41]. Furthermore, the Maillard reaction is recognized as a crucial pathway for acrylamide formation and the temperature plays a vital role in the formation of acrylamide in food. Studies have indicated that carbohydrate-rich foods exhibited elevated levels of acrylamide after heating. The degradation of carbohydrates results in the formation of acrolein [42]. For BCSs and DBCSs of 0.5 mm and 1.4 mm at 180°C, less total carbohydrates were observed (21.71 glucose eq/100 g and 17.92 glucose eq/100 g.

Correia et al. [43] studied the chemical properties of chestnut flour at various drying temperatures and found that with higher drying temperatures, there was a decrease in the starch content.

3.6. Effect of Processing Parameters on Protein Content of BCSs and DBCSs. Protein is essential for building and repairing tissues, supporting immune function, and serving as a source of energy. Table 2 presents the impact of various baking temperatures on the protein content of the chips samples.

As the baking temperature increased from 140°C to 180°C, the protein content of the baked chips sample decreased significantly ($p < 0.05$). The 0.5-mm thick sample baked at a temperature of 140°C had a protein content value of 3.92% and the sample baked at 160°C had 3.73%, whereas that baked at 180°C had a value of 3.60%. A similar trend was observed in the baked chips sample of thickness 1.4 mm. As the drying temperature increased, there was a corresponding

Table 2: Biochemical parameters of baked and dried baked coconut chip samples.

Treatment	Sample ID (°C)	Biochemical analysis				
		Moisture (w.b. %)	Ash (%)	Total carbohydrate (glucose eq/100 g)	Protein (%)	Fat (%)
0.5 mm thickness						
T1	BCS-180	2.73 ± 0.24^{ef}	0.93 ± 0.07^{bcde}	25.72 ± 0.63^{f}	3.60 ± 0.08^{c}	38.52 ± 0.8^{ab}
T2	BCS-160	3.13 ± 0.12^{cd}	1.13 ± 0.06^{ab}	31.49 ± 0.59^{c}	3.73 ± 0.07^{bc}	40.49 ± 0.8^{a}
T3	BCS-140	3.54 ± 0.11^{ab}	0.87 ± 0.04^{cde}	34.35 ± 0.73^{b}	3.92 ± 0.07^{b}	41.09 ± 0.07^{a}
T4	DBCS-180	3.02 ± 0.08^{cde}	1.05 ± 0.08^{abcd}	21.71 ± 2.21^{g}	3.65 ± 0.01^{c}	34.56 ± 0.93^{c}
T5	DBCS-160	3.17 ± 0.09^{cd}	1.12 ± 0.07^{abc}	27.96 ± 0.41^{de}	3.93 ± 0.1^{b}	36.63 ± 1.87^{bc}
T6	DBCS-140	3.79 ± 0.22^{a}	0.87 ± 0.04^{cde}	25.99 ± 0.44^{ef}	4.34 ± 0.07^{a}	37.27 ± 1.02^{bc}
1.4 mm thickness						
T1	BCS-180	2.38 ± 0.08^{cd}	0.80 ± 0.02^{cde}	23.06 ± 0.09^{e}	4.1 ± 0.01^{e}	30.88 ± 0.47^{c}
T2	BCS-160	2.57 ± 0.19^{abc}	0.86 ± 0.08^{cde}	23.88 ± 0.73^{cde}	4.3 ± 0.05^{ds}	35.1 ± 1.8^{bc}
T3	BCS-140	2.72 ± 0.15^{abc}	0.54 ± 0.34^{ef}	29.25 ± 0^{cde}	4.85 ± 0.08^{a}	43.34 ± 0.84^{a}
T4	DBCS-180	2.19 ± 0.11^{de}	0.81 ± 0.02^{cde}	17.92 ± 2.21^{cde}	4.6 ± 0.12^{c}	36.81 ± 4.43^{abc}
T5	DBCS-160	2.45 ± 0.08^{bcd}	0.86 ± 0.08^{cde}	25.74 ± 1.04^{ab}	4.64 ± 0.07^{bc}	40.92 ± 0.7^{ab}
T6	DBCS-140	2.56 ± 0.06^{abc}	0.69 ± 0.02^{def}	29.25 ± 0^{cde}	4.79 ± 0.08^{ab}	43.35 ± 4.43^{a}

Note: The different letters in the columns indicate a significant effect at a level of 0.05.
Abbreviations: BCS, baked chips sample; DBCS-dried baked chips sample.

increase in protein denaturation, leading to a substantial decrease in both protein levels [44]. The degradation of the protein content as a result of heating was reported by Gernah and Sengev [45] as well as Sengev et al. [46]. Abd Elmoneim et al. [47] state that the processing of banana chips leads to the decrease in the protein content (29.55% and 20.45%) in fried and baked chips. Hence, it is concluded that minimal processing leads to the retention of the protein content. The dried baked chips sample also followed the same trend as the baked chips sample in the case of protein content. These findings differed from another study [22] that reported no significant differences in protein content in the Gentil Rosso baking tests. In contrast, the wheat mix showed a slightly higher protein content when baked at 150°C.

3.7. Effect of Processing Parameters on the Fat Content of BCSs and DBCSs. Fat is essential for the quality of various food products, influencing both their nutritional composition and sensory attributes [48]. Table 2 presents the influence of baking temperature on the fat content of coconut chip samples of thickness of 0.5 mm and 1.4 mm. The varying baking temperatures were found to have a significant impact ($p < 0.05$) on the fat content of the coconut chips samples.

The sample of 0.5 mm and 1.4 mm thickness baked at higher temperatures (180°C) had the lowest fat content (33.82% and 30.88%, respectively). In dried baked samples, it was also observed that the fat content decreased as the baking temperature increased. It could be attributed to the oxidation of the fat content. This observation was similar to those of Ahmed et al. [49]. They observed the physiochemical properties of sweet potato flour at various drying temperatures ranging from 55°C to 65°C. The reduction in the fat content of potato flour was reported as the temperature increased from 55°C to 65°C. Baking is the method to reduce the fat content of chips rather than frying. Alfeo et al. [22] studied the impact of varying baking times and temperatures on the nutritional values of bakery products made from fresh wheat sprouts. The fat content in the wheat mix samples remained similar at baking temperatures of 100°C and 150°C. However, it was slightly higher in Gentil Rosso, a common wheat variety, when baked at 100°C.

3.8. Effect of Processing Parameters on TPC. The TPC of food can vary widely depending on factors such as the type of food, processing methods, and processing temperature. Compounds containing polyphenols play a role in antioxidant activity [50]. Table 3 shows the effect of different baking temperatures on the TPC of the coconut chips sample.

An increase in the baking temperature appears to significantly impact the TPC, resulting in an increase in these constituents up to a specific limit (160°C) and then a decrease at elevated temperatures (180°C). Higher temperatures typically enhance the solubility of phenolic compounds by causing the breakdown of cellular structures during baking. This breakdown facilitates the release of phenolics that are bound to the macromolecules of the cell wall. Furthermore, reductions in the TPC resulting from thermal degradation during dehydration could also be due to the bonding of polyphenols with other compounds, such as proteins, or changes in the chemical structure of polyphenols that cannot be detected or quantified using existing methods [51]. The higher retention of the phenolic content was found in the sample baked at 160°C with values of 0.035 mg gallic acid/100 g for 0.5 mm and 0.44 mg gallic acid/100 g for samples of a thickness of 1.4 mm. Miranda et al. [52] observed the same trend in the TPC of quinoa seeds, when the air drying temperature increased from 40°C to 80°C. Research by Alvarez-Jubete et al. [53] highlighted a reduction in the TPC following bread making with sprouted flours, and these results contrasted with another study [22] that found no significant difference in the total polyphenol content between Gentil Rosso and wheat mix bakery products compared to raw sprouts.

Table 3: Phenolic and antioxidant profiles of baked coconut chips and dried baked coconut chips samples.

Treatment	Sample ID (°C)	Total phenol (mg gallic acid/100 g)	Antioxidant	
			DPPH (%)	FRAP (mg Trolox/100 g)
0.5 mm thickness				
T1	BCS-180	0.029 ± 0^{c}	57.56 ± 0.0^{d}	0.009 ± 0.00^{a}
T2	BCS-160	0.035 ± 0^{b}	67.64 ± 0.0^{a}	0.009 ± 7.07^{a}
T3	BCS-140	0.031 ± 0^{bc}	65.02 ± 1.2^{b}	0.009 ± 2.12^{a}
T4	DBCS-180	0.032 ± 0^{bc}	51.06 ± 1.4^{e}	0.004 ± 0.00^{b}
T5	DBCS-160	0.043 ± 0^{a}	60.44 ± 1.3^{c}	0.005 ± 1.40^{b}
T6	DBCS-140	0.032 ± 0^{b}	58.15 ± 0.13^{ds}	0.005 ± 0.00^{b}
1.4 mm thickness				
T1	BCS-180	0.05 ± 0.0^{a}	67.8 ± 0.12^{c}	0.008 ± 8.5^{c}
T2	BCS-160	0.44 ± 0.5^{a}	72.78 ± 1.70^{ab}	0.011 ± 0.0^{a}
T3	BCS-140	0.08 ± 0.0^{a}	72.69 ± 1.40^{ab}	0.01 ± 0.0^{b}
T4	DBCS-180	0.03 ± 0.0^{b}	71.96 ± 0.52^{b}	0.002 ± 0.0^{e}
T5	DBCS-160	0.08 ± 0.0^{a}	74.54 ± 0.79^{a}	0.01 ± 0.0^{a}
T6	DBCS-140	0.05 ± 0.0^{a}	67.62 ± 1.20^{c}	0.005 ± 0.0^{d}

Note: The different letters in the columns indicate a significant effect at a level of 0.05.
Abbreviations: BCS, baked chips sample; DBCS, dried baked chips sample.

3.9. Effect of Processing Parameters on Antioxidant Property. Several factors affect the antioxidant activity of food, including the lipid composition, the concentration of antioxidants, the oxygen pressure, the temperature, and the presence of other antioxidants, as well as common food constituents like proteins and water [52]. Table 3 shows the effect of different baking temperatures on the antioxidant activity of 0.5-mm- and 1.4-mm-thick coconut chips sample.

The results indicated a marginal increase in antioxidant activity as the temperature increased from 140°C to 160°C, followed by a decline at 180°C. Regarding the antioxidant activity of baked chips tested using the DPPH assay and the FRAP assay, the samples with a thickness of 0.5 mm exhibited a higher value at 160°C (67.64% and 0.009 mg TE/100 g, respectively). Those that underwent temperature treatment of 140°C and 180°C showed DDPH assay values of 65.02% and 57.56%, respectively. The FRAP assay showed a constant value of 0.009 mg TE/100 g at both temperatures (140°C and 180°C). Similarly, the baked sample with a thickness of 1.4 mm exhibited a comparable trend in antioxidant activity in the DPPH assay and FRAP assay, with the highest retention value of 72.78% and 0.011 mg TE/100 g observed at a temperature of 160°C. More degradation of antioxidant activity was observed at 180°C in both the baked and dried baked samples. Such as the antioxidant activity of the BCS at 180°C measured in the DPPH assay was 67.8% and that of the DBCS was 71.96%. Similar way the measurement of the antioxidant capacity of the BCS at 180°C in FRAP assay revealed 0.008 mg TE/100 g, and those of DBCS were found to possess 0.002 mg TE/100 g.

Hwang and Lee [54] state that antioxidant activity increases with increasing baking temperature; however, elevating the temperature beyond a specific limit could result in the degradation of antioxidant activity. Sung et al. [55] studied the DPPH scavenging activity of potato chips. During baking, the potato chips developed radical scavenging activity indicated as a change in color that decreases the concentration of DPPH radicals. This finding was consistent with the study by Muhamad et al. [56] who investigated the effect of drying temperatures on the antioxidant properties of immature Manis Terengganu Melon (*Cucumis melo*). They concluded that increasing the drying temperature significantly retained the TPC to a specific limit, consequently resulting in a higher radical scavenging activity.

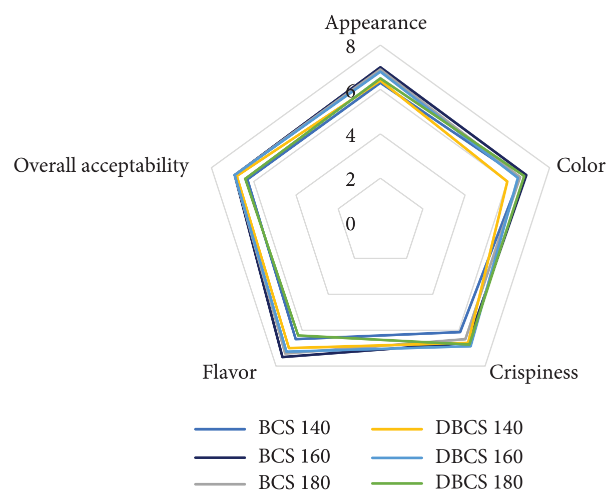

Figure 2: Sensory scores for the BCS and DBCS at 0.5 mm thickness.

3.10. Effect of Processing Methods on Sensory Evaluation of Coconut Chips. The sensory evaluation data depicted in Figure 2 indicate that the BCS with a thickness of 0.5 mm, baked at 160°C, received the highest ratings from assessors across the majority of assessed attributes. The DBCS at 160°C showed higher crispiness than the BCS sample at 160°C. The BCS at 140°C was evaluated by the panelists with the lowest score for appearance, crispiness, and overall acceptability. Generally, the BCS at 160°C obtained the highest score for their overall acceptability. Panelists have adjudged all chips samples with scores higher than 6, judging them as acceptable.

4. Conclusions

Rising health awareness has driven the demand for healthier snacks, encouraging the development of low-fat coconut chips. Baking is a promising alternative to frying, producing chips with less fat without compromising taste. This study showed that different baking temperatures (140°C, 160°C, and 180°C) significantly affect the physical and biochemical properties of coconut chips. Baking at 160°C with a thickness of 0.5 mm yielded the best results in terms of antioxidant activity, total phenol retention, and sensory quality. This information may provide significant insights for improving the production of coconut chips as a healthier snack option. However, higher temperatures (180°C) led to quality degradation. Future research should explore alternative methods like vacuum baking to further optimize production.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

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