Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension
Volume 22 Number 4 (October 2023) pp. 37 - 43
ISSN 1119-7455

EFFECT OF INCORPORATION OF PEANUT SKIN POWDER ON SOME QUALITY CHARACTERISTICS OF PEANUT (*Arachis hypogaea*) BUTTER

Asogwa I.S., *Amonyeze A.O., Onwuchekwa A.I. and Odo R.G.

Department of Food Science & Technology, University of Nigeria, Nsukka, Nigeria

*Corresponding author's email: ahunna.amonyeze@unn.edu.ng

ABSTRACT

Peanut skin is a food waste with great potentials as a source of natural antioxidants in food systems. The study examined the effect of adding peanut skin (PS) powder on selected quality characteristics of produced peanut butter. The PS powder at varying levels (1%, 2%, and 3%) was incorporated and into processed peanut butter samples. Peanut butter with no PS and commercial peanut butter served as controls. Nutrient composition, antioxidant and sensory properties of the peanut butter samples were determined. There were differences ($p < 0.05$) in all proximate composition parameters. While protein and fat content decreased, content increased with PS powder level. The protein and fat contents ranged from 24.31% to 26.28% and from 58.58% to 52.85%, respectively. The fibre content varied from 0.82 for the control sample to 1.78% for peanut butter with 3% PS. The zinc, Vitamins E and B3 levels increased with levels of PS powder. The total phenolic content ranged from 64.2 to 86.79 mg garlic acid extract (GAE) 100-g^{-1} and increased with PS powder levels. The DPPH activity (1,1-Dihenyl-2-picrylhydrazyl radical scavenging activity) increased significantly with PS powder content. The sample with 3% PS had the highest overall acceptability score. It is concluded that acceptable peanut butter with enhanced antioxidant activity could be produced by incorporating PS at up to 3% level.

Key words: peanut butter, peanut skin, proximate, micronutrient

INTRODUCTION

Arachis hypogaea L., often known as groundnuts or peanuts, is a member of the Leguminosae family. People grow it for oil extraction and food production (Janila *et al*., 2013). Sebei *et al.* (2013) stated that peanuts are considered an important source of antioxidants, protein, oil, and essential fatty acids (linoleic). Peanuts are the most important oil seed crop in the world and are high in oil (44-56%) and protein (23-20%). They are rich in polyunsaturated fatty acids, vitamins, minerals, and antioxidants, which lower cholesterol and the risk of heart disease (Win *et al*., 2011). About two-thirds of the peanuts cultivated globally are utilised to produce oil and generate products like peanut butter (Variath and Janila, 2017). Roasted snack peanuts, peanut desserts and candies, and various confectionaries are among the other products made from peanuts. Because the skin part of peanut makes up about 3% of the entire kernel mass (Hill *et al.*, 2002), a significant amount of peanut skin (PS) by-product is produced during the production of product-based peanuts. The peanut processing industry is estimated to produce over 0.74 million metric tonnes of PS annually worldwide (Sobolev and Cole, 2003). Unfortunately, because they have little to no economic value, the majority of these PSs are discarded as waste.

However, a negligible amount of these PSs is utilized as a component of cattle feed. According to Sobolev and Cole (2003), the presence of procyanidins in PSs at a rate higher than 5-8% in cow feed has a deleterious impact on protein digestion and consequently on animal performance. Its use in animal feed is further restricted by the skins' unpleasant flavor. Natural antioxidants like procyanidin and phenolic chemicals have been shown to be abundant and reasonably priced in PS (Lou *et al.*, 2004). According to Constanza *et al*. (2012), these substances found in peanut shells may have significant effects on food due to their strong antioxidant and antibacterial properties. By providing extra hydrogen electrons to free radicals, antioxidants can lower the pace of oxidation processes caused by free radicals, thereby reducing the rate of oxidative stress caused by free radicals. According to reports, long-term ingestion of PS extract rich in antioxidants offers protection against neurological illnesses, diabetes, cancer, osteo-porosis, and cardiovascular disease (Putra *et al.*, 2022). The PS has a high nutritional content in addition to antioxidant components. Nepote *et al*. (2002) found that PS provides about 140-150 mg g^{-1} of total phenolic chemicals, but it also contains 12% protein, 16% fat, and 72% carbs.

Please cite as: Asogwa I.S., Amonyeze A.O., Onwuchekwa A.I. and Odo R.G. (2023). Effect of incorporation of peanut skin powder on some quality characteristics of peanut (*Arachis hypogaea*) butter. *Agro-Science*, **22 (4),** 37-43. DOI: https://dx.doi.org/10.4314/as.v22i4.6

Research on the chemical composition and applications of plant sources high in antioxidants, like peanut shells, as functional food ingredients in the food industry (Lou *et al.*, 2004), has become more intense. According to Lorenzo *et al*. (2018), this is a result of growing customer preferences for healthier foods. With encouraging outcomes, PS has been added to a variety of food products, including bread (Sulieman *et al.*, 2014), yoghurt (Ahmed *et al.*, 2020), meat products (O'Keefe and Wang, 2006; Jianmei *et al.,* 2010), etc.

In Nigeria and many other countries of the world, peanut butter is a popular food. Cookies, biscuits, etc., are covered with peanut butter. In Nigeria, kola nuts and garden eggs are eaten with locally produced peanut butter. It is a significant object used in naming rituals, weddings, and funerals. Making peanut butter only requires shelling, dry roasting, blanching, and crushing the peanuts into a paste (Woodroof, 1983). This process is comparatively easy. To increase consumer appeal, more additives like sugar, salt, and stabilizer may be added. Stabilizers, such as hydrogenated canola, soybean, palm, cottonseed, or a combination of these oils, aid in preventing the oils from separating from the solid fractions. Research has been done on the impact of adding PS to other food products, but not much on how it affects the qualities of peanut butter. In the light of this, the purpose of this study was to determine how adding PS to peanut butter affected its physical. chemical, and antioxidant properties.

MATERIALS AND METHODS

Procurement of raw materials: The peanuts, sugar, soybean oil, salt and other ingredients were purchased from Ogige Market Nsukka, Enugu State, Nigeria.

Sample Preparation

Production of Peanut Butter: After sorting the peanuts in their shells to get rid of any stones or other undesired items, they were completely cleaned in clean water to get rid of extra dirt. After being shelled, the peanuts were cleaned and dried for one hour at 80 °C for 1 h in a convection hot air oven (Sanusi Electric Oven, Nigeria). The peanuts were then roasted for 30 min. at 160 °C in a hot air oven (Sanusi electric oven, Nigeria) to achieve the desired golden colour and flavour. After letting the peanuts cool for a full hour at room temperature, the skin was gently scraped off using both hands. The skin that was collected was ground using a 2-mm-pore-size cheese cloth (to separate fine particles and remove larger pieces) and a Panasonic MX-GX 1021 kitchen blender. For every sample (Table 1), all the materials were added, and a hand-operated portable grinder (Mill cast Manual Grain Grinder, Nigeria) was used to grind the mixture three times (to obtain a fine particle size). The resultant pastes were packaged in plastic containers and kept at room temperature.

Table 1: Formulation for peanut butter processing

Sample	Peanuts (%)	Peanut skins (%)	Salt (%)	Sugar (%)	Soybean oil (%)
PNB0	90	0	2	5	3
PNB1	89	1	2	5	3
PNB2	88	2	2	5	3
PNB3	87	3	2	5	3

PNB0 (control) - peanut butter with 0% peanut skin,
PNB1 - peanut butter with 1% peanut skin,
PNB2 - peanut butter with 2% peanut skin,
PNB3 - peanut butter with 3% peanut skin
Source: (Woodroof, 1983)

Sample Analysis

Proximate composition determination

This was done in accordance with the air oven method described in AOAC (2010), about 2 ml of the sample was transferred into a moisture dish and dried for 16-18 h at 100-102°C. After drying the sample, it was cooled by placing in the desiccator before weighing again to obtain the final weight. A 0.5 g sample was thoroughly extracted using petroleum ether in a micro Soxhlet extraction device (Gerhardt, Bonn, Germany) to assess crude fat content. The Kjeldahl method was used to determine the proteins. The amount of ash was measured by burning it for 12 h at 550°C in a Muffle furnace. Crude fiber was measured by digesting the residue with 0.128 m H_2SO_4 and then 0.223 M NaOH. It was then dried and weighed. The percentage of moisture, protein, fat, fibre, and ash that differed from 100% was used to calculate the amount of carbohydrates.

Micronutrient determination

Using the AOAC (2010) method, the mineral content of the peanut butter samples was assessed. The Atomic Absorption Spectrophotometer (Buck Scientific 210 CGP, USA) was used to measure the following elements: zinc, phosphorus, magnesium, iron, and vitamins B_3 and E.

Physicochemical and phytochemical evaluation

As stated by AOAC (2010), the total phenolic and flavonoid components were ascertained through the use of a UV spectrophotometer. Using the technique outlined by AOAC (2010), total solids and viscosity (measured using an Amatek Brookfield viscometer at room temperature) were calculated.

Antioxidant activities

The determination of 1,1-Dihenyl-2-picrylhydrazyl radical scavenging activity (DPPH) was carried out using the method described by AOAC (2010) with slight modification. After shaking 300 uL+ of the extract with 3 ml+ of a methanolic solution containing 0.02 mM DPPH, it was allowed to sit at room temperature for half an hour. Subsequently, absorbance readings at 517 nm were taken using a spectrophotometer (UV mini-1240, Shimadzu, Japan). Ascorbic acid, methanol reagent, and DPPH served as the standard, blank, and positive controls,

respectively. The following equation was used to calculate the DPPH scavenging activity:

Scavenging activity (%) = (Control Absorbance – Absorbance of sample)/Control absorbance × 100

Reducing power assay

With a few changes, the assay was conducted using the methodology described by (Hossain *et al.*, 2014). To stop the reaction, 2.5 ml of tricholroacetic acid (10%, w/v) was added to a mixture containing 1 ml of extract, 2.5 ml of potassium ferricyanide [K_3Fe (CN)6] (1%, w/v), and 0.2 M phosphate buffer (pH 6.6). The combination was formed and incubated at 50°C for 20 minutes. Following a 10-min. centrifugation at 1000 g for the samples, 2.5 mL+ of the supernatant was combined with 0.5 mL+ of ferric chloride (0.1%, w/v) and 2.5 mL+ of distilled water. At 700 nm, the solution's absorbance was measured using ascorbic acid standards at varying doses and distilled water as a blank.

Water activity

The water activity of the peanut butter samples was determined using the water activity meter in the lab

Sensory Evaluation

The sensory evaluation was conducted using a 20 panelist from the University of Nigeria Nsukka's Department of Food Science & Technology to evaluate the freshly made items based on their sensory qualities. It was asked of the panelists what samples they preferred. The product was assessed using a 9-point hedonic scale, as outlined by Ihekoronye and Ngoddy (1985), with 9 representing the best score and 1 the lowest, for each quality, including appear-ance, flavour, mouthfeel, and overall acceptability.

Experimental Design/Data Analysis

The experiment was based on a completely randomized design. Data analysis was done using a one-way analysis of variance was used for the analyses. Duncan's New Multiple Range Test was used to differentiate significant means, and version 22 of SPSS (Statistical Package for Social Sciences) was used to accept significance at ($p < 0.05$).

RESULTS AND DISCUSSION

Effect of Peanut Skin (PS) Incorporation on the Proximate Composition of the Formulated Peanut

Table 2 shows the effect of PS incorporation on the proximate composition of the formulated peanut. All proximate composition metrics showed significant ($p < 0.05$) variations across the samples, with the exception of carbohydrate. The moisture level ranged from 2.20% to 4.22%, the protein content from 24.31% to 26.28%, and the crude fat percentage from 52.83% to 52.83%, respectively. PNB0 exhibited the maximum values for every previously mentioned parameter. The addition of PS resulted in a decrease ($p < 0.05$) in the levels of fat and protein. Ranges of 2.19-3.68% was observed for the ash content, 0.82-1.76% for crude fiber, and 8.86-15.38% for carbohydrates.

The lower moisture content of peanut skin (PS) compared to peanuts, the main ingredient in peanut butter processing, may be the cause of the decreased moisture content with PS inclusion. According to reports, roasted peanuts have a moisture percentage of 2.62-3.45% (Ukwo *et al.* 2019). Unsubstituted peanut butter's moisture content likewise matches the range of 1.23-4.30% given by Boli *et al.* (2017). Food texture, nutritional profiles, flavor profiles, and food safety are all impacted by moisture content. The rates of lipid oxidation, microbial growth, and browning all change when food's moisture content varies. The samples containing PS had lower moisture levels, which suggests better shelf stability. The reduced protein composition of the PS containing samples may be caused by the dilution effect of lower protein PS. The protein content of PS is reported to be 9.2%, whereas that of peanuts is approximately 39%. (Sulieman *et al.*, 2014). The protein concentration of the peanut butter in this investigation is consistent with the 23.33-28.58% figure reported by Afolabi *et al.* (2018), who also found that the non- supplemented peanut butter had a protein content of 25.50%. These high protein contents support the notion that peanut butters could be regarded as an excellent, reasonably priced source of protein to help improve the nutritional status of people living in impoverished nations (FAO/WHO, 2007).

The inclusion of PS resulted in a decrease in crude fat content. Given that PS has less fat than peanuts, this is to be expected. Sulieman *et al*. (2014) reported that PS had a fat content of 4.6%. According to reports, peanuts have a 47.00% fat content (Atasie *et al.*, 2010). In comparison to the 41-48% crude fat values published by Makeri *et al.* (2011) for peanut paste made with two Nigerian cultivars of *Arachis hypogeae*, the crude fat content of the peanut butter samples is greater. Boli *et al.* (2017) discovered that the range of peanut butters sold in Abidjan was 46.12-49.32%. The variations could result from the usage of various peanut varietals and processing techniques. The lower fat content of these PS containing samples could be beneficial to health-conscious individuals who are either managing obesity or trying to prevent it.

The ash content of the samples containing PS may have increased due to PS's higher ash content than peanuts. According to reports, peanuts have an ash level of 4.00% (Ukwo *et al.*, 2019). The PS has been found to have an ash concentration of 9.42% (Sulieman *et al.*, 2014). The study's peanut butter samples' ash contents compare favorably to the 3.16-3.26% reported by (Shibli *et al.*, 2019). Increased ash content is associated with increased mineral levels, which is advantageous, particularly in poor nations where micronutrient shortages, including those in iron and zinc, are common.

Table 2: Effect of peanut skin incorporation on the proximate composition (%) of formulated peanut butter samples

Samples	Moisture	Crude Protein	Crude Fat	Ash	Crude Fibre	Carbohydrate
PNB0	$4.22^{a}\pm0.09$	$26.28^{a}\pm0.00$	$58.58^{a}\pm0.54$	$2.19^{e}\pm0.00$	$0.82^{d}\pm0.04$	$7.91^{c}\pm1.40$
PNB1	$2.29^{e}\pm0.00$	$25.98^{a}\pm0.00$	$57.94^{ab}\pm1.24$	$2.68^{c}\pm0.02$	$1.10^{c}\pm0.07$	$10.01^{bc}\pm3.42$
PNB2	$2.20^{e}\pm0.02$	$25.26^{b}\pm0.00$	$57.10^{b}\pm0.16$	$3.04^{b}\pm1.00$	$1.5^{b}\pm0.05$	$10.90^{b}\pm3.02$
PNB3	$2.28^{e}\pm0.02$	$24.31^{c}\pm0.00$	$55.92^{c}\pm0.32$	$3.68^{a}\pm0.00$	$1.76^{a}\pm0.01$	$12.05^{a}\pm4.23$
COMM	$2.90^{b}\pm0.00$	$25.31^{b}\pm0.00$	$52.83^{c}\pm0.83$	$2.38^{d}\pm0.00$	$0.20^{e}\pm0.00$	$16.38^{a}\pm2.24$

PNB0 (Control) - peanut butter with 0% peanut skin, PNB1 - peanut butter with 1% peanut skin, PNB2 - peanut butter with 2% peanut skin, PNB3 - peanut butter with 3% peanut skin, COMM - commercial control. Values are means of ± standard deviations of replicate determinations. Means with different superscripts within the same column are significantly ($p < 0.05$) different.

For PNB0, the crude fiber content was 0.82%, while for PNB3, it was 1.76%. As the amount of PS increased, so did the crude fiber content. This is a result of PS having more crude fiber than peanuts. Sulieman *et al.* (2014) reported that PS had 11.7% crude fiber content, whereas Atasie *et al.* (2009) found that peanuts had 3.7% crude fiber. According to Shibli *et al*. (2019), the crude fiber results for the peanut butter samples are lower than the fiber content (2.11-4.46%) of peanut butters sold in Pakistan.

For PNB0 and PNB%, the carbohydrate content varied from 7.91% to 12.05%. As the amount of PS increased, so did the carbohydrate content. This may be explained by the supplemented samples having lower quantities of crude protein and crude fat, which raised their levels of carbohydrates.

It is possible to infer that the formulated peanut butter samples are high in fat and protein from the proximate composition result. They also have modest ash levels, which suggests moderate mineral content.

Effect of Peanut Skin (PS) Incorporation on the Micronutrient Composition of Formulated Peanut Butter Samples

Table 3 shows the effect of PS incorporation on the micronutrient composition of formulated peanut butter samples. All micronutrient compositions evaluated varied significantly ($p < 0.05$) among samples. There were significant increases in all the micronutrients with PS substitution except for iron where a decrease was observed. The ranges of values for magnesium, zinc and phosphorus contents were 54.28-65.91, 0.65-1.44 and 430.33-593.61 mg 100-g^{-1}, respectively. The values for iron varied from 0.47 to 1.73 mg 100-g^{-1}. Vitamins E and B3 concentrations ranged from 2.82 to 3.92 mg 100-g^{-1} and from 2.12 to 7.90 mg 100-g^{-1} for samples PNB0 and COMM, respectively.

The increase in Mg, Zn indicates that PS is richer in those minerals than peanut butter. The Mg and Zn contents of the samples were lower than 146.73-203.3 mg 100-g^{-1} and 2.34-3.37 mg 100-g^{-1} reported by Shibli *et al.* (2019). The variation could be attributed to varietal differences. The decrease in Phosphorus and iron levels with addition of PS suggests that PS has lower phosphorus and Fe than peanut butter. The iron content of 1.6-1.96 mg 100-g^{-1} was obtained by Shibli *et al.* (2019) for peanut butter samples made from different cultivars of peanut sold in Pakistan which agrees with 1.73 mg 100-g^{-1} obtained in this study for the formulated non-supplemented butter. The results implied that PS is rich in both vitamins E and B3. The increasing values for vitamin E are significant because of its antioxidant properties.

The results from the micronutrient composition of the formulated peanut butter samples showed that the addition of PS would improve the micronutrient composition of peanut butter (except from iron and phosphorus). This is noteworthy since deficiencies in zinc have well-known functional effects, such as impaired immunological function, impaired physical growth, impaired reproductive function, and impaired neuro-behavioral development (Brown *et al.* 2004). These functional consequences which are linked to stunted childhood growth, elevated child morbidity and mortality, and unfavourable maternal health and pregnancy outcomes have the biggest effect in environments with low intakes of absorbable zinc, such as low- and middle-income countries (LMICs) (Gupta *et al.*, 2020).

Effect of Peanut Skin Incorporation on the Phytochemical Composition of Produced Peanut Butter

Table 4 shows the effect of PS incorporation on the phytochemical composition of the produced peanut butter. Incorporating peanut peel significantly ($p < 0.05$) led to increases in the total phenol (mg GAE 100-g^{-1}), and flavonoid (mg GAE 100-g^{-1}) contents of the peanut butter samples. The phenolic and flavonoid concentrations of the formulated peanut butter ranged from 64.25 to 86.79 and from 5.48 to 6.54 mg GAE 100-g^{-1}, respectively. Sample

Table 3: Effect of peanut skin incorporation on the micronutrient composition of formulated peanut butter (mg 100-g^{-1})

Samples	Magnesium	Zinc	Phosphorus	Iron	Vitamin E	Vitamin B_3
PNB0	$54.28^{e}\pm0.04$	$0.65^{e}\pm0.01$	$593.61^{a}\pm3.78$	$1.73^{a}\pm0.12$	$2.82^{e}\pm0.00$	$2.12^{e}\pm0.02$
PNB1	$58.41^{d}\pm0.00$	$0.95^{d}\pm0.00$	$590.91^{a}\pm1.06$	$1.37^{b}\pm0.12$	$3.07^{d}\pm0.00$	$4.21^{d}\pm0.08$
PNB2	$61.60^{c}\pm0.09$	$1.04^{c}\pm0.02$	$585.04^{b}\pm0.29$	$1.12^{c}\pm0.02$	$3.55^{c}\pm0.06$	$4.64^{c}\pm0.16$
PNB3	$63.35^{b}\pm0.39$	$1.44^{b}\pm0.04$	$501.64^{c}\pm0.74$	$0.70^{d}\pm0.04$	$3.79^{b}\pm0.02$	$6.49^{b}\pm0.03$
COMM	$65.91^{a}\pm0.01$	$2.25^{a}\pm0.00$	$430.33^{d}\pm0.78$	$0.47^{e}\pm0.01$	$3.92^{a}\pm0.00$	$7.90^{a}\pm0.18$

PNB0 (Control) - peanut butter with 0% peanut skin, PNB1 - peanut butter with 1% peanut skin, PNB2 - peanut butter with 2% peanut skin, PNB3 - peanut butter with 3% peanut skin, COMM - commercial control. Values are means of ± standard deviations of replicate determinations. Means with different superscripts within the same column are significantly ($p < 0.05$) different.

Table 4: Effect of peanut skin incorporation on the phytochemical composition of produced peanut butter

Samples	Phenols (mg GAE 100-g^{-1})	Flavonoids (mg QE 100-g^{-1})
PNB0	64.25^{c}±0.70	5.48^{d}±0.00
PNB1	71.34^{b}±0.57	5.63^{cd}±0.07
PNB2	73.37^{b}±0.17	5.90^{b}±0.06
PNB3	86.79^{a}±0.65	6.54^{a}±0.10
COMM	73.00^{b}±1.76	5.86^{bc}±0.13

PNB0 (Control) - peanut butter with 0% peanut skin,
PNB1 - peanut butter with 1% peanut skin,
PNB2 - peanut butter with 2% peanut skin,
PNB3 - peanut butter with 3% peanut skin,
COMM - commercial control,
GAE - Gallic acid equivalent, QE - Quercetin equivalent. Values are means of ± standard deviations of replicate determinations. Means with different super- scripts within the same column are significantly ($p < 0.05$) different.

PNB3 (3% PS addition) has the highest contents of phenol (86.79 mg GAE 100-g^{-1}) and flavonoid (6.54 mg GAE 100-g^{-1}), while sample PNB0 (formulated control samples) had the lowest contents of phenols (64.25 mg GAE 100-g^{-1}) and flavonoid (5.48 mg GAE 100-g^{-1}), indicating that PS is a good source of natural antioxidants.

According to some descriptions, the most significant phenolic and antioxidant components found in PSs are proanthocyanidins. Both peanuts and PSs have been shown to contain resveratrol (Sobolev *et al.,* 1995; Sobolev and Cole, 1999; Sanders *et al.,* 2000). It is noteworthy the both the phenolic and flavonoid levels at 3% addition of PS were much high than the commercial control. The commercial control is preserved with synthetic anti-oxidant. This underscores the multiple benefits of using natural antioxidants which will not only stabi-lise the oils but offer health benefits as well. Strong antioxidants such phenolic compounds are known to lower the risk of degenerative diseases, cancer, diabetes, and cardiovascular illnesses. For usage in food and dietary supplements, PS may offer a cheap source of naturally occurring antioxidants such as procyanidin and catechins (Sulieman *et al.*, 2014).

Effect of Peanut Skin (PS) Incorporation on the Antioxidant Activity of Produced Peanut Butter

Figure 1 shows the effect of PS incorporation on the antioxidant activity of formulated peanut butter. There were significant ($p < 0.05$) increases in both the DPPH activity and reducing power with increase in the level of incorporated PS. The DPPH ranged from 8.40% for COMM to 39.04% for PNB3, while the reducing power ranged from 37.93% for PNB0 to 43.07% for PNB3.

The increase in antioxidant activity with increase in PS could be attributed to its rich phenolic content and other compounds with high antioxidant activity. Such phenolic compounds include proanthocyanidins and resveratrol in addition to being safe, PS extract has greater in vitro antioxidant activity than vitamin C and Trolox, according to Yu *et al.* (2005). The methanolic, ethanolic, and aqueous extracts of PS exhibited DPPH activity percentages more than 93% in Nepote *et al.*'s (2002) investigation, showing good radical-scavenging activity. Also, PS at a dosage of 0.2 g kg^{-1} was shown by Nepote *et al.* (2004) to have a protective effect against lipid oxidation in honey-roasted peanuts. According to Yu *et al.* (2010), butylated hydroxyanisole (BHA) at 0.2 g kg^{-1} was less effective in preventing lipid oxidation than PS at values more than 0.6 g kg^{-1} in both raw and cooked beef (O'Keefe and Wang, 2006). Because PS has a high level of antioxidant activity, it can be used as a functional dietary ingredient to improve health and lower the risk of degenerative diseases like cardiovascular disease.

Resveratrol has been shown to have antimuta-genic and antioxidant properties as well as cancer chemopreventive action in mice. By preventing or changing platelet aggregation and coagulation, or by modifying lipoprotein metabolism, it is also linked to a lower risk of cardiovascular disease (Bertelli *et al.*, 1995; Pace-Asciak *et al.*, 1995).

The Effect of Peanut Skin (PS) Incorporation on the Total Solid and Viscosity Properties of Produced Peanut Butter

Table 5 shows the results of the effect of PS incorporation on the total solids and viscosity properties of produced peanut butter. Incorporating PS significantly increased the total solid content and viscosity of formulated peanut butter samples ($p < 0.05$), with values ranging from 39.40 to 50.69 g 100-g^{-1} and 24.49 to 55.63 MPa s^{-1}, respectively. Both the total solid and viscosity increased with PS addition. The commercial sample had the lowest scores for the two measured parameters. There was a high positive correlation (coefficient of linear correlation = 97%) between total solids and viscosity, indicating that as more solids were incorporated via the PSs, the thickness of the butter increased.

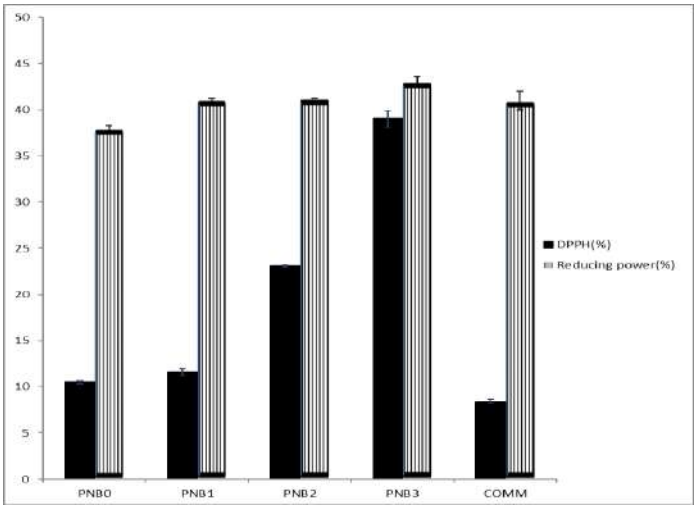

Figure 1: Effect of peanut skin incorporation on the antioxidant activity of formulated peanut butter
PNB0 (Control) - peanut butter with 0% peanut skin,
PNB1 - peanut butter with 1% peanut skin,
PNB2 - peanut butter with 2% peanut skin,
PNB3 - peanut butter with 3% peanut skin,
COMM - commercial control

Table 5: The effect of peanut skin incorporation on the total solid and viscosity properties of formulated peanut butter samples

Samples	Total solids (mg g^{-1})	Viscosity (MPa s^{-1})
PNB0	45.07^{c}±0.53	46.36^{d}±0.41
PNB1	46.57^{b}±0.45	48.03^{c}±0.45
PNB2	47.56^{b}±0.14	50.30^{b}±0.60
PNB3	50.69^{a}±0.51	55.63^{a}±0.30
COMM	39.59^{d}±0.12	24.40^{e}±0.30

PNB0 (Control) - peanut butter with 0% peanut skin,
PNB1 - peanut butter with 1% peanut skin,
PNB2 - peanut butter with 2% peanut skin,
PNB3 - peanut butter with 3% peanut skin,
COMM - commercial control
Values are means of ± standard deviations of replicate determinations. Means with different super scripts within the same column are significantly ($p < 0.05$) different.

It is worth noting that both the total solid and viscosity of the commercial control were lower ($p < 0.05$) than the experimental samples. This could be due to variations in the variety of peanuts used and the processing methods employed.

Effect of Peanut Skin Incorporation on the Sensory Scores of Produced Peanut Butter Samples

Table 6 shows the effect of PS incorporation on the sensory scores of produced peanut butter samples. The mean scores for colour, aroma, oiliness, and consistency did not differ significantly ($p > 0.05$). However, the mean scores for appearance, taste, flavour, spreadability, aftertaste, sweetness, mouthfeel, and general acceptability were different ($p < 0.05$). The scores for colour and oilness ranged from 7.00 for PNB3 to 7.60 for PNB1 and from 6.60 for PNB2 to 7.15 for COMM. Spreadability and mouthfeel scores ranged from 6.25 for PNB3 to 7.55 for COMM and 5.90 for COMM to 6.95 for both PNB0 and PNB2. The overall acceptability scored varied from 6.20 for COMM to 7.70 for PNB2. It is noteworthy that the samples of peanut butter produced did not differ ($p > 0.05$) among themselves in most of the sensory parameters evaluated (except for appearance and taste). It is also noteworthy that these samples scored higher than the commercial sample in general acceptability. The lower scores for the commercial control could be due to the lower nutty and roasted taste of the exotic sample than the formulated ones. This result shows that the addition of PS up to 3% did not negatively affect the acceptability of peanut butter. This is very interesting as PS has a slight astringent taste but rather than depreciating the acceptability, the slight bitter taste was appreciated.

CONCLUSION

This study evaluated the effect of peanut skin powder addition on some quality parameters of peanut butter. Proximate composition was significantly influenced by peanut skin levels while protein, moisture, crude fat, decreased ash and crude fibre contents increased. There were increased in zinc, magnesium, vitamins E and B_3 with PS addition. Adding PS also increased the phytochemical and antioxidant activity of the peanut butter samples. It is worth noting that adding up to 3% peanut skin would not reduce the acceptability of peanut butter, and its incorporation into peanut butter production could help to significantly boost the health-promoting ability of the peanut butter due to enhanced phytochemical content and antioxidant activity.

Table 6: The effect of peanut skin incorporation on the sensory scores of peanut butter

Parameters	PNB0	PNB1	PNB2	PNB3	COMM
Colour	7.40^{a}±1.04	7.60^{a}±0.88	7.30^{a}±0.97	7.00^{a}±1.02	7.50^{a}±1.05
Appearance	7.55^{a}±0.75	7.50^{a}±0.94	7.50^{a}±0.94	6.50^{b}±1.35	6.95^{ab}±1.57
Aroma	7.60^{a}±0.75	7.20^{a}±0.76	7.95^{a}±1.79	7.15^{a}±1.13	6.60^{a}±1.46
Oilness	7.05^{a}±1.70	6.80^{a}±1.36	6.60^{a}±1.27	6.65^{a}±1.59	7.15^{a}±1.18
Spreadability	7.20^{ab}±1.64	6.65^{ab}±1.22	6.40^{b}±1.81	6.25^{a}±1.59	7.55^{b}±1.23
Taste	7.50^{b}±1.35	7.00^{ab}±1.58	7.65^{a}±1.30	7.70^{a}±0.94	5.40^{c}±1.87
Aftertaste	7.00^{a}±1.02	6.70^{a}±1.55	7.25^{a}±1.51	7.40^{a}±0.40	4.85^{b}±1.84
Flavour	7.40^{a}±0.99	7.05^{a}±1.31	7.20^{a}±1.15	7.25^{ab}±1.40	5.20^{b}±1.60
Mouthfeel	6.95^{a}±1.27	6.80^{ab}±1.39	6.95^{a}±1.43	6.90^{a}±1.02	5.90^{b}±2.02
Consistency	7.10^{a}±0.78	6.85^{a}±1.30	7.00^{a}±1.25	6.90^{a}±1.16	6.95^{a}±0.78
Overall Acceptability	7.50^{a}±1.19	7.50^{a}±1.14	7.70^{a}±1.17	7.65^{a}±0.87	6.20^{b}±1.79

PNB0 (Control) - peanut butter with 0% peanut skin, PNB1 - peanut butter with 1% peanut skin, PNB2 - peanut butter with 2% peanut skin, PNB3 - peanut butter with 3% peanut skin, COMM - commercial control. Values are means of ± standard deviations of replicate determinations. Means with different super scripts within the same column are significantly ($p < 0.05$) different.

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