LWT - Food Science and Technology 88 (2018) 126–131

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Value added snacks produced from Bambara groundnut (*Vigna subterranea*) paste or flour

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ARTICLE INFO

Keywords:
Bambara groundnut
Cowpea
Akara egbe
Sensory
Hardness

ABSTRACT

Bambara groundnut is an underutilised leguminous crop that has similar composition to cowpea. In this study, snacks were prepared from Bambara groundnut flour or paste in comparison with cowpea. The proximate composition, colour, sensory properties and effect of storage period on the colour and texture of the snack were assessed. Protein and carbohydrate were the main components of Bambara groundnut flour and the snack. Snacks prepared from Bambara groundnut flour showed higher protein content (23.41 g/100 g) than the sample made from Bambara groundnut paste (19.35 g/100 g). Generally, snacks prepared from paste had higher ratings in all sensory attributes than those made from the flour. Colour intensity of the snacks slightly decreased, while the samples picked up moisture during storage. Storage of the snacks in high density polyethylene bags under ambient conditions of about 25 °C can keep the samples for less than 4 wk, as samples showed evidence of mould growth at 4 wk.

1. Introduction

Akara Ogbomoso also known as *akara egbe* is a traditional snack native to Ogbomoso town in Oyo state, Nigeria. It is produced mainly from cowpea (*Vigna unguiculata*) paste seasoned with salt, flattened with the palm and deep-fried in vegetable oil to produce a reddish brown, hard textured, low moisture product (Falade, Adedeji, & Akingbala, 2003). The snack may be consumed alone or in combination with cereal porridge and soaked *gari* (Falade et al., 2003). Although the consumption of this snack was previously limited to the area of production, there seems to be an increasing demand for its consumption in other regions of the country. For instance, the snack is now being sold in supermarkets after value addition through the addition of flavouring materials and packaging. The increased demand for this snack, locally and internationally, especially by Nigerians residing abroad who relish the traditional taste of the snack, suggest the need to increase production and possibly seek for alternative material for its production.

Cowpea is the main raw material used in the production of this snack. However, other pulses such as Bambara groundnut (*Vigna subterranea*) are promising alternatives to cowpea for its production. This is because the grains of Bambara groundnut have similar composition to that of cowpea (Oyeyinka, Singh, Adebola, Gerrano, & Amonsou, 2015). Bambara groundnut is rich in protein (19–28 g/100 g) and carbohydrate (57–68 g/100 g) (Arise, Amonsou, & Ijabadeniyi, 2015; Kaptso et al., 2014; Oyeyinka et al., 2015). The proteins of Bambara groundnut may be used as a functional ingredient in the industry due to its balanced amino acid profile (Bamshaiye, Adegbola, & Bamishaiye, 2011) and the antioxidant properties of its protein hydrolysate and peptide fractions (Arise et al., 2016). Furthermore, Bambara groundnut stands out in its relatively higher methionine compared to other commonly consumed legumes including soya bean. Despite these nutritional attributes, Bambara groundnut remains an underutilised crop mainly grown for subsistence. In Africa including Nigeria, Bambara groundnut has been used in the production of puddings (*Okpa*) (Barimalaa & Anoghalu, 1997), kangu (Adefalu & Fawole, 2014) and milk (Brough, Azam-Ali, & Taylor, 1993; Murevanhema & Jideani, 2015). Other reports have shown that Bambara groundnut is rich in starch (Kaptso et al., 2014; Oyeyinka, Singh, & Amonsou, 2016a; Oyeyinka et al., 2015), which can be modified for improved functionality and application in the industry (Afolabi, 2012; , Singh, & Amonsou, 2017; Oyeyinka, Singh, Ma, & Amonsou, 2016b; Oyeyinka, Singh, Venter, & Amonsou, 2016c; Oyeyinka, Singh, Ying, & Amonsou, 2016d).

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http://dx.doi.org/10.1016/j.lwt.2017.10.011
Received 23 August 2017; Received in revised form 28 September 2017; Accepted 5 October 2017
Available online 07 October 2017

Despite the enormous potentials of Bambara groundnut, the crop remains a traditional crop with limited utilisation. To further increase the utilisation of Bambara groundnut beyond traditional usage, it may be important to explore some value added processing methods that have been previously used for similar pulses such as cowpea. Hence, the grains of Bambara groundnut could offer some potential for utilisation in making snacks similar to those prepared from cowpea grains. Previous studies reported the use of Bambara groundnut in making balls (*akara*) in comparison with cowpea after pretreatments such as wet-milling and autoclaving (Alobo, 1999). According to their report, *akara* from autoclaved Bambara groundnut had higher rating compared to *akara* from other pretreatments. Furthermore, with the exception of the appearance and colour, there was no significant differences between Bambara groundnut *akara* and the cowpea reference *akara* (Alobo, 1999). *Akara* has a higher (almost triple) moisture content than the typical *akara egbe*, and may rapidly deteriorate due to its high moisture content. Hence, producing snacks with a relatively low moisture content may be a promising alternative to extend the shelf life of this product. Therefore, this study investigated the proximate and sensory properties of snacks prepared from Bambara groundnut flour and paste. The colour and hardness of the snacks were also assessed after storage for 4 wk. Cowpea was included as the reference sample.

2. Materials and methods

2.1. Materials

Bambara groundnut and cowpea were obtained from Oja oba market in Kwara State, Nigeria. The grains were sorted and transferred into the Food Processing Laboratory, Department of Home Economics and Food Science, University of Ilorin, Nigeria for further processing.

2.2. Preparation of Bambara groundnut flour, paste and snacks

Bambara groundnut flour was prepared as previously reported (Oyeyinka et al., 2015). Briefly, Bambara groundnut was dehulled, dried at 60 °C for 48 h in the oven (D-37520, Thermo Fisher Scientific, Germany), ground into flour and sieved (sieve aperture size: 355 μm). Cowpea flour was produced in the same manner as described for Bambara groundnut. Flour samples were stored at 4 °C until analyzed.

The paste was prepared by dehulling the seeds and milling into a thick paste. Paste was also made from the flour samples as previously reported (Falade et al., 2003). Salt was added to the both paste samples, stirred for proper mixing and flattened with the palm. The flattened paste wase deep-fried in vegetable oil (specific gravity = 0.916) at 170 ± 5 °C for 5 min. The samples were drained packaged in Ziploc bag and used immediately for analysis.

2.3. Analyses

2.3.1. Proximate composition of flour and the snacks

Moisture, fat and ash contents were determined using AOAC (2000) methods. Protein content was determined by the Kjeldahl method (6.25 × N) and total carbohydrate was calculated by difference. Fiber content was determined by digestion in sulfuric acid and sodium hydroxide (Kirk & Sawyer, 1991).

2.3.2. Sensory properties

Sensory evaluation of the samples was carried out as described by Karim, Kayode, Oyeyinka, and Oyeyinka (2015). Briefly, a 9- point hedonic preference scale and a multiple comparison test were used to assess the acceptability of snacks made from Bambara groundnut paste and flour in comparison with those made from cowpea paste and flour. Fifty (50) semi-trained panellists, selected from student of the Department of Home Economics and Food Science, University of Ilorin, Nigeria were used for the evaluation. The selected students were those accustomed to eating *akara egbe*. Prior to the sensory analysis, they were screened with respect to their interest and ability to differentiate food sensory properties. The samples were evaluated for aroma, colour, taste, crunchiness and overall acceptability.

2.3.3. Storage of snacks

Freshly prepared snacks were kept in high density polyethylene bags for a period of 4 wk at room temperature (25 ± 2 °C). Hardness and colour parameters of the samples were determined at an interval of 1 wk for the period of storage.

2.3.4. Water absorption and hardness of stored snacks

The water absorbed by the stored samples was estimated by determining the weight gain in g for a period of 4 wk. Weight gain is believed to result from the absorbed moisture during storage and was calculated by subtracting the initial weight of the samples before storage from the final weight after storage.

The hardness of the snacks was determined by measuring the breaking force in newton using a Shimadzu texture analyser (EZ-SX, China). Snacks of similar thickness were selected and placed in the instrument.

2.3.5. Colour parameters

The CIE tristimulus L, a, and b parameters of the freshly prepared and stored *snacks* were measured using a using chroma meter (ColourFlex-Diffuse). The colorimeter operates on the CIE L, a and b colour schemes, L (lightness) axis – 0 is black, 100 is white, a (red-green) axis-positive values are red; negative values are green and 0 is neutral, b (yellow-blue) axis-positive values are yellow; negative values are blue and 0 is neutral. The instrument was standardized and the samples were placed in the sample holder. Colour measurement was determined in triplicates.

2.4. Statistical analysis

All analyses were performed in triplicate. Data was analyzed using analysis of variance (ANOVA) and means were compared using the Fisher Least Significant Difference (LSD) test ($p < 0.05$).

3. Results and discussion

3.1. Proximate composition of Bambara groundnut and cowpea flours

The major components of the flours were protein and carbohydrate (Table 1). Bambara groundnut had higher protein (23.71 g/100 g) and moisture (8.73 g/100 g) contents than cowpea flour (protein: 19.47 g/100 g; moisture: 8.45 g/100 g). Legumes may show variable compositional data depending on source, origin and processing conditions. The protein content in the Bambara groundnut flours is in agreement with values (21–28 g/100 g) previously reported (Adebowale, Afolabi, & Lawal, 2002; Arise et al., 2015; Oyeyinka et al., 2015). Moisture, ash, fat and fibre contents of the flour samples were generally low. Low fat contents in both Bambara groundnut and cowpea flours is

Table 1
Proximate composition of Bambara groundnut and cowpea flours (g/100 g).

Parameters	Bambara groundnut	Cowpea
Moisture	$8.73^{a} \pm 0.02$	$8.45^{b} \pm 0.01$
Protein	$23.71^{a} \pm 0.01$	$19.47^{b} \pm 0.01$
Fat	$4.25^{b} \pm 0.01$	$6.66^{a} \pm 0.01$
Ash	$3.82^{b} \pm 0.01$	$4.25^{a} \pm 0.21$
Fibre	$1.47^{b} \pm 0.01$	$2.43^{a} \pm 0.03$
Carbohydrate	$58.32^{a} \pm 0.02$	$58.48^{a} \pm 0.03$

Mean ± Standard deviation. Mean with different superscript along the row are significantly different ($p < 0.05$).

Table 2
Proximate composition of snacks prepared from Bambara and cowpea (g 100 g).

Sample	Bambara groundnut		Cowpea	
	Flour	Paste	Flour	Paste
Moisture	$8.13^{b} \pm 0.01$	$8.22^{a} \pm 0.05$	$8.15^{b} \pm 0.01$	$8.24^{a} \pm 0.14$
Protein	$23.41^{a} \pm 0.01$	$19.35^{b} \pm 0.01$	$19.37^{b} \pm 0.01$	$19.33^{b} \pm 0.01$
Fat	$8.45^{c} \pm 0.01$	$8.87^{b} \pm 0.01$	$8.37^{d} \pm 0.01$	$9.28^{a} \pm 0.03$
Ash	$3.98^{d} \pm 0.01$	$4.25^{b} \pm 0.01$	$4.23^{c} \pm 0.01$	$4.29^{a} \pm 0.01$
Fibre	$1.46^{b} \pm 0.01$	$2.38^{a} \pm 0.01$	$2.39^{a} \pm 0.01$	$2.38^{a} \pm 0.01$
Carbohydrate	$54.59^{d} \pm 0.01$	$56.95^{b} \pm 0.01$	$57.52^{a} \pm 0.01$	$56.49^{c} \pm 0.01$

Mean ± Standard deviation, Mean with different superscript along the row are significantly different ($p < 0.05$).

expected since these crops are pulses. Pulses generally have very low oil contents usually below less than 10 g/100 g when compared to oil seeds such as soybean.

3.2. Proximate composition of freshly made snacks

The proximate composition of the snacks from Bambara groundnut and cowpea showed that protein (19.33–23.41 g/100 g) and carbohydrate (54.59–57.52 g/100 g) were the major components in the samples (Table 2). Ash (3.98–4.29 g/100 g), fibre (1.40–2.39 g/100 g), fat (8.37–9.28 g/100 g) and moisture (8.13–8.24 g/100 g) contents were low (Table 2). Snacks prepared from Bambara groundnut flour showed significantly ($p = 0.05$) higher protein content (23.41 g/100 g) than snacks made from the paste (19.35 g/100 g). The same trend was observed for snacks made from cowpea grains. However, the protein content of snacks prepared from Bambara groundnut was generally higher than that made from cowpea. In comparison with the raw flour (Table 1), there was a slight reduction in protein contents after making the snacks. The slight reduction in protein content could be attributed to the influence of heat and possibly the interactions of the amino groups of proteins with the carbonyl group in sugars leading to maillard browning. Falade et al. (2003) reported slightly lower protein content (18.8 g/100 g) for similar snacks prepared from cowpea flour. Differences in the cowpea variety used in the respective studies may have accounted for the variation in protein content. The fat contents of snacks prepared from Bambara groundnut (8.87 g/100 g) and cowpea (9.28 g/100 g) paste were significantly ($p = 0.05$) higher than those made from the flour for both Bambara groundnut (8.45 g/100 g) and cowpea (8.37 g/100 g) (Table 2). The higher fat content in the snacks made from paste compared to those made from the flour could be attributed to two reasons. Firstly, it is possible that the sieving reduced the amount of hydrophobic components that could absorb oil. Another plausible reason could be due to the effect of drying on the structure of the flour. Drying causes a change in structure reducing the degree of rehydration and absorption.

These values were higher than the fat contents of the grains (Bambara groundnut: 4.25 g/100 g, cowpea: 6.66 g/100 g) from which they were prepared (Table 1). The relatively higher fat content of the snacks compared to the fat content of the grains could be attributed to uptake of oil during frying. During frying of most foods, both water and water vapour are removed from the surface and interior of the food and are replaced by hot oil. The fat contents of the snacks in this study are much lower than values reported (11.8–37.8 g/100 g) for snacks prepared from cowpea flour substituted with soy bean flour (Falade et al., 2003). The variation in fat contents could be due to the addition of soy bean flour which is rich in oil. Moisture contents of the snacks were low (8.13–8.24 g/100 g) and are similar to values (7.6–8.3 g/100 g) previously reported (Falade et al., 2003). Moisture content is an important indicator of shelf life. Foods with low moisture content are not good breeding grounds for micro-organisms.

3.3. Sensory evaluation of freshly made snacks

Snacks prepared from Bambara groundnut paste generally had higher ratings in aroma, colour, crunchiness and overall acceptability than their counterparts prepared from the flour. The same trend was observed for the cowpea snacks. It is interesting to note that the taste ratings for snacks prepared from Bambara groundnut flour was significantly ($p < 0.05$) higher than that recorded for the paste samples. The reason for this remain unclear. However, it is possible that the heat applied during drying of the flour possibly enhanced the taste of the snacks prepared from Bambara groundnut flour. Previous reports showed that thermal treatment of Bambara groundnut influenced the level of acceptability of the *akara* (bean balls) (Alobo, 1999). In comparison with the control snacks prepared from cowpea flour and paste, the ratings recorded for Bambara groundnut were slightly lower. It is possible that the familiarity of the samples from the cowpea paste influenced the preference by the panel members.

3.4. Appearance of freshly prepared and stored snacks

The appearance of the paste made from the grains directly and from the flour of both Bambara groundnut and cowpea flours as well as the fried snacks is shown in Fig. 1. Snacks prepared from Bambara groundnut flour had similar appearance to those made from the cowpea and were both ligther than their paste counterparts (Fig. 1). The colour of the samples varied from golden brown to dark brown which may be due to maillard browning resulting from the reaction between the amino group of amino acids and carbonyl group of sugars. After storage for 4 wk, mould growth were evident on all the samples except snacks prepared from Bambara groundnut paste (Fig. 2). Furthermore, the ability of the snacks to absorb water which was assessed over a 4 wk period showed that the snack absorbed water differently (Fig. 3). The difference in the initial weight of the samples as well as the their final weight after storage was used to compute the amount of water absorbed. Snacks made from Bambara groundnut paste absorbed about 0.40 g compared to samples prepared from Bambara groundnut flour (0.58 g), cowpea flour (0.60 g) and cowpea paste (0.81 g) (Fig. 3). The relatively lower amount of water absorbed by the snack made from Bambara groundnut paste may explain why the sample made from Bambara groundnut paste had no mould growth.

3.5. Hardness of freshly prepared and stored snacks

The hardness of the snacks varied significantly ($p < 0.05$) between 89.39 N and 98.48 N for snacks prepared from Bambara groundnut flour and cowpea flour respectively (Table 4). Falade et al. (2003) reported similar hardness value for snacks prepared from cowpea flour. The hardness of the snacks decreased with increase in storage period, which could be associated with the moisture absorbed during storage (Fig. 3). Furthermore, it appears that the snack that absorbed more water (Fig. 3) during storage had the lowest hardness (Table 4),

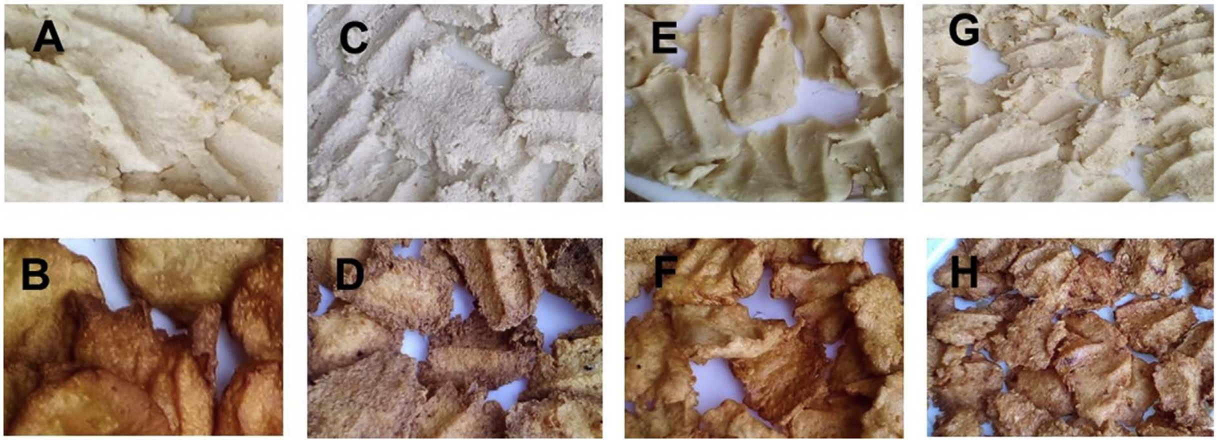

Fig. 1. Paste and snacks prepared from Bambara groundnut and cowpea.
A: Paste prepared from Bambara groundnut flour.
B: Snack prepared from Bambara groundnut flour.
C: Paste prepared from Bambara groundnut seed.
D: Snack prepared from Bambara groundnut seed.
E: Paste prepared from cowpea flour.
F: Snack prepared from cowpea flour.
G: Paste prepared from cowpea seed.
H: Snack prepared from cowpea seed.

Fig. 2. Appearance of Bambara groundnut and cowpea snacks after 4 weeks of storage.
Arrows indicate mould growth on snacks.
A: Snacks prepared from Bambara groundnut flour.
B: Snacks prepared from Bambara groundnut past.
C: Snacks prepared from cowpea flour.
D: Snacks prepared from cowpea paste.

confirming the influence of the moisture on the evidence of mould growth on the snacks prepared from cowpea paste (Fig. 2).

3.6. Colour parameters of freshly prepared and stored snacks

Objective colour measurement of the snacks using Hunter lab colorimeter showed that a and b values (data not shown) and the lightness values (L) of freshly prepared samples from Bambara groundnut flour were significantly ($p < 0.05$) higher than those of the paste samples (Fig. 4). The same trend was observed for the cowpea reference sample. Furthermore, the colour parameters observed for the Bambara groundnut samples were significantly ($p < 0.05$) higher than those of the cowpea samples. The colour results suggest that snacks prepared from cowpea were browner than those of Bambara groundnut. The objective measurement result seems to be in agreement with the subjective sensory results, since snacks made from Bambara groundnut flour had higher preference in colour than the snacks from the paste (Table 3). With increasing period of storage, the colour parameters significantly ($p < 0.05$) increased suggesting that the colour of the samples became lighter. The increase in weight of the samples as evident in the water absorbed (Fig. 3) may explain the changes in colour of the samples (Fig. 4). Furthermore, oxidative changes caused by the

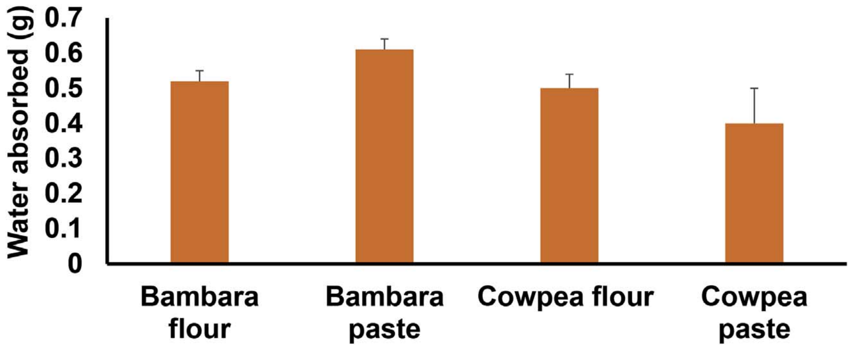

Fig. 3. Water absorbed by snacks prepared from Bambara groundnut and cowpea.
Error bars indicate standard deviation (N = 10).
*Water absorbed was calculated as difference between final weight after storage and initial weight.

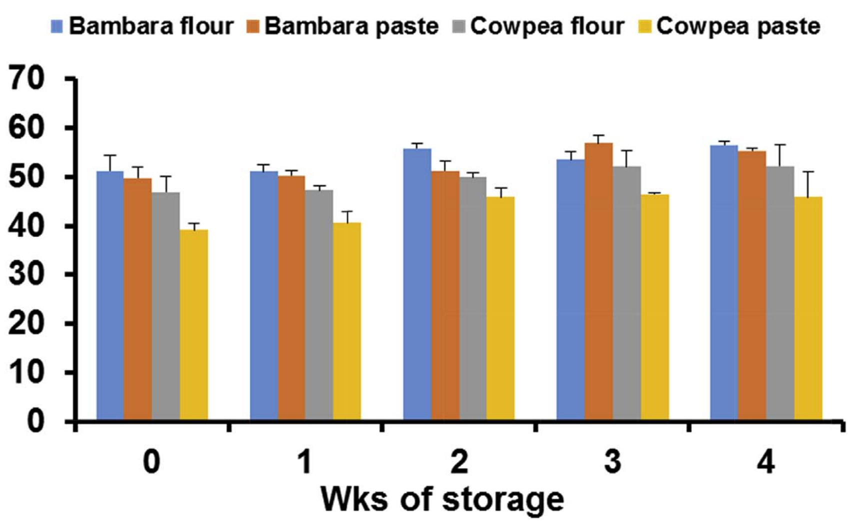

Fig. 4. Lightness values of snacks prepared from Bambara groundnut and cowpea.
Error bars indicate standard deviation (N = 3).

Table 3
Mean sensory scores of snacks prepared from Bambara groundnut and cowpea.

Sample	Bambara groundnut		Cowpea	
	Flour	Paste	Flour	Paste
Aroma	$5.80^{a} \pm 1.75$	$6.20^{ab} \pm 1.64$	$6.20^{ab} \pm 1.57$	$6.68^{a} \pm 1.65$
Colour	$6.76^{a} \pm 1.50$	$6.86^{a} \pm 1.42$	$6.92^{a} \pm 1.29$	$7.06^{a} \pm 1.41$
Taste	$5.58^{a} \pm 1.81$	$4.56^{b} \pm 2.19$	$5.48^{a} \pm 1.92$	$5.98^{a} \pm 1.66$
Crunchiness	$5.98^{c} \pm 2.40$	$6.78^{ab} \pm 1.61$	$6.46^{ab} \pm 2.00$	$7.48^{a} \pm 1.39$
Overall acceptability	$5.52^{c} \pm 1.91$	$6.50^{b} \pm 1.52$	$6.06^{c} \pm 1.66$	$7.24^{a} \pm 1.15$
Total score	29.64	30.90	31.12	34.44

Mean ± Standard deviation, Mean with different superscript along the row are significantly different ($p < 0.05$).

Table 4
Hardness of snacks prepared from Bambara groundnut and cowpea stored in polythene for 4 weeks (N).

Weeks	Bambara groundnut		Cowpea	
	Flour	Paste	Flour	Paste
0	$89.39^{c} \pm 0.56$	$96.30^{b} \pm 0.14$	$89.76^{c} \pm 0.03$	$98.48^{a} \pm 0.42$
1	$86.85^{d} \pm 0.04$	$92.37^{b} \pm 0.01$	$87.21^{c} \pm 0.04$	$95.45^{a} \pm 0.07$
2	$85.76^{c} \pm 0.98$	$88.91^{b} \pm 0.16$	$84.61^{c} \pm 0.69$	$91.25^{a} \pm 1.02$
3	$84.07^{c} \pm 0.26$	$86.79^{b} \pm 0.28$	$82.04^{d} \pm 1.05$	$88.90^{a} \pm 0.16$
4	$77.25^{c} \pm 0.21$	$82.51^{a} \pm 0.38$	$78.04^{b} \pm 0.08$	$75.08^{d} \pm 0.03$

Mean ± Standard deviation, Mean with different superscript along the row are significantly different ($p < 0.05$).

presence of oxygen within the packaging material which could alter the physical appearance of the samples may also be responsible for the change in colour.

4. Conclusion

Snacks with comparable nutritional and sensory properties to that made from cowpea was produced from Bambara groundnut flour or paste. Bambara groundnut and cowpea snacks are good sources of protein and carbohydrate. Sensory properties of snacks made from the paste were superior to that made from the flour. Colour of the snacks slightly decreased, while the samples pciked up moisture during storage. Storage of the snacks in high density polyethylene bags under ambient conditions of about 25 ± 2 °C can keep the samples for less than 4 wk, as samples showed evidence of mould growth at 4 wk of storage. Future studies are required to identify the microbiome in the snakcs and possibly add spices as ingredients during the formulation to further extend the shelf-life.

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