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Optimization of Nutritional and Pasting Properties of Rice-Sweet Potato Based Composite Flour for Biscuit Production

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ABSTRACT

Rice-sweet potato based biscuit was produced from optimization of the composite flour. The composite flour consisted rice, sweet potato and soybean flours with carboxyl methylcellulose as binder. Experimental design and statistical analysis were carried out using optimal mixture design of response surface methodology. The proximate compositions were optimized while the pasting characteristics and amino acid profile of the optimum blends were evaluated. The sensory evaluation and mechanical properties of the biscuit produced were also determined. The result showed that 15 of the 16 samples had protein content above 10 g/100g. This value is considerable if compared with 100% wheat flour. Samples 6 (85.694% rice flour, 11.806% sweet potato and 2.5% CMC) and 7 (95% rice flour, 2.5% sweet potato flour and 6.765% CMC), specifically, had high levels of ash, fibre and protein contents. In addition, all the samples had carbohydrate content above 70 g/100g. The result of the pasting characteristics showed that the composite flour had good flour quality. The addition of the binder (carboxyl methyl cellulose) enhanced the pasting properties. In addition, the amino acid profile showed that the composite flour had all the nine essential amino acids. The biscuit produced had good mechanical and sensory properties.

Key words: biscuit, composite flour, rice flour, sweet potato, pasting characteristics

INTRODUCTION

Biscuits and other bakery products such as bread and cakes prepared from wheat flour are stable food consumed worldwide. Research into production of biscuit and other bakery products from non-wheat raw materials is gaining momentum in particular because of people with gluten-intolerance and also to locally available crops rich such as cereals and legumes for baked products rich in nutrients and antioxidants. Precisely, cereals, legumes and tubers are being utilized for the production of composite flours which have advantages of being rich in protein, fibre and antioxidants (Awolu *et al.,* 2015; Awolu *et al.,* 2016). Nutritionally rich and health-promoting cookies have been produced from composite flours sourced from rice, cassava, kersting's groundnut, bambara groundnut, apple pomace, cocoyam and carrot (Awolu *et al.,* 2015; Awolu *et al.,* 2016).

Less than half of the rice consumed in Nigeria are produced locally. 'Igbemo' rice is local rice commonly produced and consumed in Ekiti State and other parts of Nigeria (Oyedele and Adeoti, 2013). Rice is a staple food in many developing countries (Hauser, 2003) and it is excellent source of vitamin E, B vitamin (thiamin, niacin), potassium and very high in carbohydrate. Sweet potatoes (*Ipomoea batatas* L.) are rich in calories, dietary fiber, good sources of antioxidants and polyphenols (Teow Choong *et al*., 2007; Ahmed *et al*., 2010), zinc, potassium, iron, sodium, calcium, magnesium and manganese (Antia *et al*., 2006). Soybean (*Glycine max*) is an excellent source of protein (Serrem *et al*., 2011) and rich in lysine. Carboxyl methylcellulose (CMC) is the sodium salt of carboxyl methylcellulose and it is the natural polysaccharide found in all plants. It is an important industrial polymer with a wide range of applications in textiles, papers, foods, and drugs (Biswal and Singh, 2004). The salt is used in baked goods and ice cream to prevent staling and ice crystal respectively, as well as emulsifier in chewing gum, peanut butter and margarine production.

This study was aimed to produce rice-sweet potato based composite flour for the production of biscuit that is rich in protein, fibre, minerals and antioxidants. It is enriched with soybean in order to enhance its protein contents while CMC was added as a binder. The proximate composition was optimized using optimal design of response surface methodology in order to determine the optimum flour blend with best proximate composition and evaluate the effect of the independent variables on the dependent variables (responses).

MATERIAL AND METHODS

Raw materials

Local rice ('*Igbemo*'), sweet potatoes, soybean and Carboxylmethyl cellulose (CMC) were obtained from Akure, Ondo State, Nigeria. Instron Universal Testing machine was obtained from Engineering Materials Development Institute (EMDI), Akure, Nigeria; Rapid Visco Analyser was obtained from research laboratory, Federal University of Technology, Akure, Nigeria.

Production of rice flour

Rice flour was produced using the methods of Falola *et al.* (2013). Igbemo rice (1 kg) was cleaned, sorted and soaked in water for 12 h. It was then washed and oven-dried at 60ºC until constant moisture was obtained and then cooled. The dried, cooled rice was milled using an attrition mill, stored at room temperature inside a sealed plastic container for further processing.

Production of soybean flour

The production of soybean flour was done according to Oluwamukomi *et al.* (2005). The soybean seeds were sorted, washed and boiled in water at 100ºC for 30 min. It was dehulled manually, oven-dried at 55ºC for 16 h, milled in a disc attrition mill, sieved through a 300 µm aperture sieve and kept in an airtight high-density polyethylene (HDPE) bag at room temperature for further processes.

Production of sweet potato flour

Sweet potatoes tubers (2.5 Kg) were thoroughly washed in order to remove extraneous matters. It was then manually peeled and cut into slices. Sweet potatoes slices were soaked in 0.2% sodium metabisulphite for 30 min to prevent enzymatic browning, oven-dried at 60ºC until 5% moisture content was obtained, milled and sieve through a 300 µm mesh. The flour was then stored for further use (Zainun *et al.,* 2005).

Experimental design and Statistical Analysis

Experimental design and statistical analysis were carried out using optimal mixture design of response surface methodology (Design expert 8.0.3.1 Trial version). The variables were rice flour (75-95 g); sweet potato flour (2.5-10.0 g) and CMC (2.5-15.0 g). Soybeans flour was constant at 5 g. The response (dependent variable) was proximate compositions. The optimum blends (based on protein, fibre and ash contents) generated from the statistical analysis were used for further analyses (pasting properties, amino acid profile and cookies production).

Determination of proximate composition of composite flour

Moisture, total ash, crude fat and crude fibre contents of the composite flours were determined using the standard methods of Association of Official Analytical Chemists (AOAC, 2005). Carbohydrate content was determined by difference.

Determination of pasting properties of composite flour

Pasting properties were determined using the Rapid Visco Analyser (RVA). The composite flour sample (3.5 g) was weighed and dispensed into the test canister. Distilled water (25.0 ml) was thereafter dispensed into the canister (14% moisture basis). The visco analyser was switched on and the pasting performance of the flour was automatically recorded on the graduated sheet of the instrument.

Analysis of amino acids profile

The amino acid compositions of the composite flours were determined using an automated amino acid analyser after hydrolyzing the samples with 6 M HCl at 110ºC for 24 h (Bassler and Buchholz, 1993). The sulphur-containing amino acids was oxidised using performic acid before the acid hydrolysis. The tryptophan content of the samples was determined spectrophotometrically by the method of Pinter-Szakacs and Molnar-Perl (1990).

Production of biscuit

Two best blends based on the optimization of the proximate composition, pasting characteristics and amino acid profile were used for biscuit production. The method described by Oluwamukomi, *et al.* (2011) was used for the biscuit production with slight modification. The ingredients used were 10 g sugar, 5 g fat, 2.0 g sodium bicarbonate and 76 ml of water in addition to the composite flours. Sugar and fat (margarine) were mixed together with the composite flour, sodium-bicarbonate and water to prepare the dough. Circular biscuits were cut (using a circular biscuit-cuter of diameter 3 cm), placed on a greased baking foil paper and kept at a normal room temperature for 2 h to allow proper dough leavening. The trays of the eight blends were baked at once in a hot air oven at a temperature of 184ºC for 15-20 min when a very light brown colour was formed. Biscuits were then removed, allowed to cool, and stored.

Sensory evaluation of biscuit produced

The sensory evaluation of the biscuits was determined using a 9-point hedonic scale where 9 stands for extremely like and 1 for extremely dislike. Ten trained panellists were used in order to test for crispiness, colour, flavour, mouth feel, texture, taste and overall acceptability.

Mechanical properties of biscuits produced

The mechanical properties of the biscuits (such as true strain at break, energy at break and the modulus) were determined using Instron Universal Testing Machine.

RESULTS AND DISCUSSION

Proximate composition of the composite flour blends

The results of the proximate compositions of the flour blends are presented in Table 1. The protein content of the blends ranged between 9.013% and 12.863%. The considerable high values of the protein could be due mainly to the presence of 5% soy bean flour added to all the blends. Soybean has been known to have high protein contents. The result of ANOVA buttrresed the point that rice, sweet potato and CMC were not good sources of protein as the p-values were not significant ($p>0.05$). In addition, the R^2 (0.6203) and adjusted R^2(0.5619) obtained are indication of the fact that samples A, B and C were not sources of high protein contents observed in the study. Thus, addition of soybean or a legume is required in the production of composite flour from rich cereal or tubers (starchy food)-based sources (Awolu *et al.*, 2015; Awolu *et al.*, 2016). The 3D plot showing the effect of samples A, B and C on the protein content is shown in Fig 1.

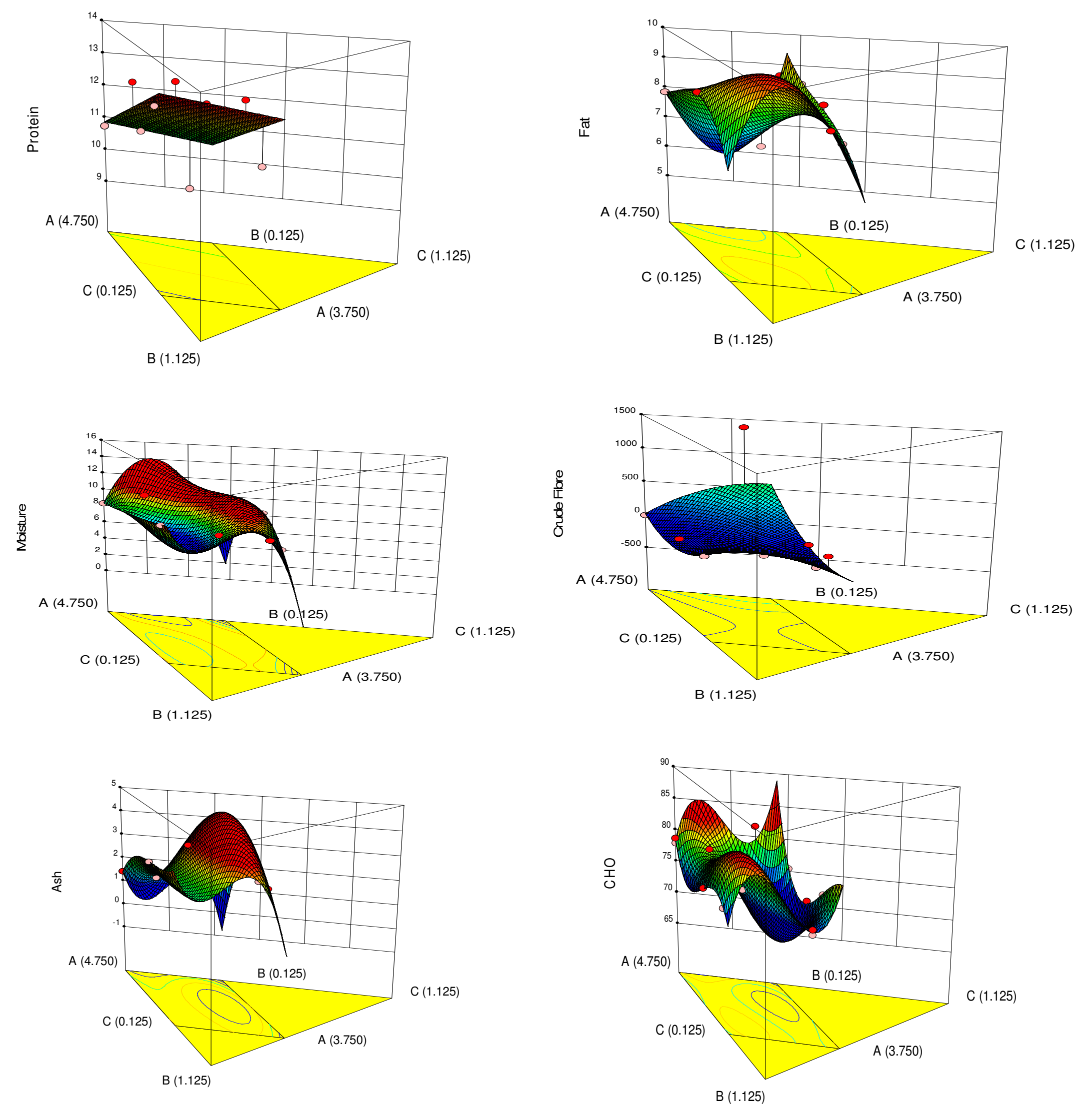

Figure 1: Fig. 1. 3D plot showing the effect of samples A, B and C on the protein, fat, moisture, crude fibre, ash content and CHO (carbohydrate) content of the composite flour. *X1=A (rice starch), *X2=B(CMC), *X3=C(sweet potato flour)

The plot showed that the effect of the samples on the protein were constant.

Fat content of the composite flour ranged between 6.261 and 9.588%. The result of ANOVA showed that the model terms (independent variables) did not significantly (p>0.05) affect the fat contents. Whereas the R^2 was high (0.8133), the adjusted R^2 value was 0.5535 which is a pointer that samples A, B and C were not good sources of fat. Soybean has high fat contents, hence, it could be the source of the fat content observed. The 3D plot showing the effect of samples A, B and C on the fat content is shown in Fig 1. The sweet potato and CMC had positive effect on the fat content (yellow/reddish region) while rice flour had the least effect on fat content (as indicated by the blue-colour). The crude fibre values obtained (0.620% - 2.150%) falls within the recommended value which is ≤ 5 g/ 100 g dry matter (FAO/WHO, 1994). None of rice flour, CMC and potato flour is a good source of fibre as shown by the ANOVA result where samples A, B and C did not show significant (p>0.05) fibre content effects. However, past report had revealed that soybean is also a good source of fibre (Mesfin and Shimelis, 2013). The R^2 and adjusted R^2 values obtained from this study were 0.3689 and 0.0534 respectively. The 3D plot,which revealed the fibre content of samples A, B and C shown in (Fig 1) showed the effect of formulations of the samples on the crude fibre to be low (blue coloured region) with exception in sweet potato which has highest.

The moisture content ranged from 4.410% to 10.459%. It has been reported that the lower moisture content of food enhances its keeping quality and shelf life (Bothast *et al.* 1991). The 3D plot showing the effect of samples A, B and C on the ash content is shown in Fig1. As shown in the plot, sweet potato flour had high positive effect on the moisture content (reddish region).

The ash content ranged from 1.207% to 3.435%. The result of the ANOVA showed that the model and model terms (linear mixture, AC, BC, ABC, AB(A-B), AC(A-C) and BC(B-C) were significantly different (p≤0.05). Meanwhile, the R^2 and adjusted R^2 values were 0.9809 and 0.9523 respectively. These statistical results that showed the samples are good sources of mineral elements (ash). Sweet potatoes, rice and soybean had been found to have positive effect on ash (Okoye *et al.,* 2008, Mesfin and Shimelis, 2013). The 3D plot showing the effect of samples A, B and C on the moisture content is shown in Fig1. Thus, the effect of sweet potato on the ash content was very high (as indicated by the reddish region)

The carbohydrates content ranged from 73.020% to 81.716%. The result of the ANOVA showed that the and model terms (linear mixture, AB, AC, BC, ABC, AB(A-B), AC(A-C) and BC(B-C) were significantly different (p≤0.05). The R^2 and adjusted R^2 values were 0.8863 and 0.7158 respectively. Rice and sweet potato are good sources of carbohydrate. The 3D plot showing the effect of samples A, B and C on the carbohydrate content is shown in Fig 1. Rice flour and CMC had high positive effect on the carbohydrate content. However, the low contribution of sweet potato flour might be as a result of its low content in the composite flour.

Optimum blends

The optimum samples from the optimisation of proximate analysis were samples 6 and 7. The samples had the overall best protein, ash and crude fibre contents.

Table 1: Proximate Composition of the Flour Blends

S/N	A %	B %	C %	Moisture (g/100g)	Protein (g/100g)	Fat (g/100g)	Fibre (g/100g)	Ash (g/100g)	CHO (g/100g)
1	95	2.5	2.5	8.589	9.013	6.261	1.803	1.207	81.716
2	82.668	11.553	5.778	7.357	10.981	7.55	2.065	2.369	77.035
3	90.792	3.507	5.701	10.064	12.688	7.427	1.785	3.056	75.044
4	75	15	10	8.41	10.763	7.879	1.83	1.446	78.082
5	82.503	7.497	10	10.064	12.688	7.427	1.785	3.056	75.044
6	85.694	11.806	2.5	9.497	12.731	8.284	2.15	3.053	73.782
7	95	2.5	2.5	10.331	12.53	8.403	1.993	2.875	74.199
8	79.764	15	5.236	9.497	12.731	8.284	2.15	3.053	73.02
9	89.47	8.03	2.5	8.901	12.731	9.588	1.383	3.278	78.082
10	85.694	11.806	2.5	8.41	10.763	7.879	1.83	1.446	78.829
11	75	15	10	10.459	10.981	7.549	1.028	1.613	78.829
12	87.5	2.5	10	8.41	10.763	7.879	1.83	1.446	78.082
13	79.764	15	5.236	9.124	11.288	7.905	1.385	1.732	77.69
14	87.5	2.5	10	8.352	12.854	8.168	0.848	3.435	74.695
15	79.058	11.042	9.9	8.517	11.419	8.657	1.208	1.841	76.875
16	85.253	7.982	6.765	9.476	12.863	8.616	0.62	2.793	75.108

* A-Rice; B-Carboxyly methylcellulose; C- Sweet potatoes

Table 2: The Pasting Properties of the Composite Flour Blends

S/N	A%	B%	C%	PV (RVA)	Trough (RVA)	BD (RVA)	FV (RVA)	SB (RVA)	Pt (min)	PT (°C)
6	85.694	11.806	2.5	227.5	93.75	133.75	242.58	148.83	5.55	81.25
7	95	2.5	2.5	243.5	91.33	152.17	258.58	167.25	5.63	83.08

* A-Rice; B-Carboxyly methylcellulose; C- Sweet potatoes. Sample 6 = 85.694% rice flour, 11.806% CMC and 2.5% sweet potato flour. Sample 7 = 95% rice flour, 2.5% CMC and 2.5% sweet potato flour. PV – peak viscosity, T – trough, BD – breakdown viscosity, FV – final viscosity, SB – setback, Pt – peak time, PT – pasting temperature

Pasting properties of the optimum composite flour

The results of the pasting characteristics of the two best composite flour blends are presented in Table 2. The peak viscosity of run 7 (243.50) is higher than run 6 (227.50) which might be a result of the higher content of rice flour. The peak viscosity is often correlated to the final product quality and provides an indication of viscous load likely to be encountered during mixing (Maziya-Dixon *et al.,* 2007). The result also showed that the higher rice flour content resulted in better pasting properties than higher CMC. Considering the better pasting quality of run 7, it has been established that rice flour had good pasting behaviour (Danbaba *et al.*, 2011), which makes it a preferred flour material for the production of stiff dough products with better palatability and water binding capacity. This attributes could thus, be exploited for the development and utilization of the new varieties in rice value-chain. The pasting temperature is a measure of minimum temperature require to cook a given food sample while peak time is a measure of cooking time (Adebowale *et al*., 2008). The current study showed run 6 had low peak time (5.55mins) compare to run7 (5.63mins).

The setback viscosity indicates the tendency of the dough to undergo retrogradation. The setback values for run 6 and 7 are 148.83 and167.25 respectively. A higher set back can reduce the dough digestibility (Shittu *et al.*, 2001) and lower setback value indicate lower tendency for retrogradation (Sandhu *et al.*, 2007). It can be inferred that increasing the content of the binder (CMC) did not improve the pasting quality of the blends.

Amino acid profile of the composite flour

The results of the amino acid profile of the optimum composite flour blends are presented in Table 3. The most abundant of the amino acid is glutamic acid and lowest is tryptophan. Glutamic acid is the most abundant amino acid in the body found in blood plasma, cerebral and spinal fluid (Hawkins, 2009). Demand for glutamic acid increases with physical and mental stress. Also, it has been found to be reduced with age. In such cases external supplements have been recommended. This food product which has very high glutamic acid could be a potential source to be very useful for people in the cases mentioned above.

Predominant amino acids are leucine, phynylalanine, isoleucine, valine, threonine, histidine, lysine, and methionine (Table 3) while tryptophan has been found to be deficient in rice and soybean (Amankwah *et al.,* 2015). Cereals and legumes have been reported as good sources of high essential amino acids (Nwokolo, 1996).

Table 3: Amino acid Profile of the Composite Flours Blends (mg/100g)

Amino Acid	Sample 6	Sample 7
Histidine	188.54	186.64
Threonine	246.34	243.24
Isoleucine	330.25	327.44
Leucine	845.25	841.04
Phenylalanine	349.34	344.27
Tryptophan	43.37	42.28
Valine	329.95	327.73
Methionine	128.24	127.86
Lysine	185.54	182.25±
Total EAA	2,646	2,622.75
Glycine	249.31	247.76
Serine	348.84	346.64
Tyrosine	248.65	246.27
Proline	596.34	580.54
Arginine	279.32	278.93
Glutamic Acid	1395.01	1387.5
Cysteine	102.03	101.2
Alanine	509.32	510.04
Total NEAA	3,728.82	3,698.88
Total AA	6,375.64	6,321.63

*Sample 6: rice flour = 85.694, CMC = 11.806, sweet potato flour = 2.500; *Sample 7: rice flour = 95.000, CMC = 2.5000, sweet potato flour = 2.500

Sensory evaluation of the composite flour biscuit

The result of the sensory evaluation of the biscuit produced from the best formulations is presented in Table 4a. There was no significant ($p>0.05$) difference in the crispiness, colour, flavour, mouth feel, texture, taste and general acceptability of the two samples. All the ratings were above 7 (moderately like) while some were close to 8 (like very much). In a newly developed product like biscuit, consumer acceptance is very important. Therefore, the result showed a product with high acceptability (Omoba *et al.,* 2013).

Mechanical properties of the biscuit

Mechanical properties of the biscuit are presented in Table 5. True stress at break of the biscuit is the force required

Table 4: Sensory Evaluation of the biscuit

No.	Crispiness	Colour	Flavour	Mouthfeel	Texture	Taste	Acceptability
6	7.62[a]	7.00[a]	7.87[a]	7.37[a]	7.37[a]	7.75[a]	7.50[a]
7	7.38[a]	7.12[a]	7.12[a]	7.37[a]	7.25[a]	7.75[a]	7.50[a]

*A-Rice flour; B-Carboxyl methylcellulose; C-Sweet potatoes; Soybean was kept constant at 5%;
Sample 6 = 85.694% rice flour, 11.806% CMC and 2.5% sweet potato flour
Sample 7 = 95% rice flour, 2.5% CMC and 2.5% sweet potato flour

Table 5: Mechanical properties of the biscuit

S/N	A%	B%	C%	True stress (MPa)	True strain (mm/mm)	Energy at break. (J)	Moduls. (MPa)
6	85.694	11.806	2.5	0.08295	0.88893	0.3542	0.58487
7	85.47	2.5	2.5	0.02983	1.80004	0.48356	0.35328

*A: Rice flour; B: Carboxyl methyl cellulose; C: Sweet potatoes flour
Sample 6 = 85.694% rice flour, 11.806% CMC and 2.5% sweet potato flour
Sample 7 = 95% rice flour, 2.5% CMC and 2.5% sweet potato flour

to rupture it. True stress for run 6 is 0.02983 MPa while the true stress of run 7 is 0.08295Mpa. The only reason for the lower true stress value of run 6 was the lower amount of rice flour in the composite flour. The present result showed that the force to rupture run 7 would be higher than run 6. True strain at break of the biscuits is the time required for the biscuits to be ruptured. Also run 7 had higher true strain value at break (1.80004 mm/mm) than run 6 (0.88893mm/mm). This shows that biscuits from run 7 cannot be easily ruptured. The energy at break for runs 6 and 7 are 0.35420J and 0.48356J respectively. The modulus for run 6 (0.58587MPa) is greater than modulus for run 7 (0.48356MPa). Therefore, the results from mechanical tests of the two runs revealed run 7 to be more preferable to run 6.

CONCLUSION

The use of mixture model of response surface methodology had assisted in analysing a large variation of the variables and helped in selecting optimum samples with the best nutritional composition for biscuit production. The composite flour had good pasting properties. The addition of CMC acts as a substitute to gluten which enhance its pasting characteristics. The addition of soybean flour also enhanced the protein content and amino acid profile of the composite blends with acceptable sensory attributes. It can be concluded that the rice-sweet potato based composite flour could serves as right alternative to wheat flours in the production of biscuits.

CONFLICT OF INTERESTS

Authors declare there are no conflicts of interests

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