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The effect of oat bran and psyllium husk fibre on oil reduction and some physicochemical properties of *magwinya* – a deep-fried dough

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ABSTRACT

Oat bran (OB) and psyllium husk fibre (PF) were incorporated into *magwinya* (fat cake) – a cereal fried dough with the aim of reducing oil content and evaluating some of its physicochemical properties using one-factor of the response surface methodology. Two methods of *magwinya* processing were employed: traditional (TM) and modified (MM) methods. Addition of PF and OB significantly ($p < 0.05$) reduced oil in MM compared to TM. Lowest oil content for PF and OB *magwinya* were 3.10 and 4.35% using MM and 6.00 and 6.25% for TM. Addition of PF up to 3% and OB up to 2% significantly improved textural properties. Comparing the additives and the method of production, optimum conditions with highest desirability of 0.83 was obtained for OB modified *magwinya* with 35.08% moisture, 2.31% ash and 4.74% oil. Hence, the use of MM and OB reduced oil absorption.

Efecto que provoca el añadido de salvado de avena y fibra de cáscara de psilio en la reducción de aceite y en algunas propiedades fisicoquímicas de la *magwinya*, una masa frita en abundante aceite

RESUMEN

Se incorporó salvado de trigo (OB) y fibra de cáscara de psilio (PF) a la *magwinya* —una especie de buñuelo frito, elaborado con cereales— con el fin de reducir su contenido de aceite y evaluar algunas de sus propiedades fisicoquímicas, para lo cual se empleó uno de los factores de la metodología de superficies de respuesta. Con este objetivo se utilizaron dos métodos de elaboración de la *magwinya*: método tradicional (TM) y métodos modificados (MM). La adición de PF y OB redujo significativamente ($p < 0.05$) el aceite en aquella preparada mediante MM en comparación con la preparada por TM. El contenido de aceite más bajo de la *magwinya* hecha con PF y OB fue 3,10% y 4,35% usando MM, y 6,00% y 6,25% para TM. Asimismo, se logró mejorar significativamente las propiedades texturales adicionando PF hasta 3% y OB hasta 2%. Comparando los elementos adicionados y el método de producción utilizado, se constató que las condiciones óptimas que obtuvieron la mayor preferencia de 0,83 consistieron en *magwinya* modificada con OB con 35,08% de humedad, 2,31% de ceniza y 4,74% de aceite. En consecuencia, el uso de MM y OB redujo la absorción de aceite.

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KEYWORDS

Oat bran; psyllium husk fibre; oil; *magwinya*: colour; texture; fat cake

PALABRAS CLAVE

salvado de trigo; fibra de cáscara de psilio; aceite; *magwinya*; color; textura; buñuelo



Introduction

Magwinya, also known as “fat cakes” is a traditional deep-fried bread/cake flour dough which resembles doughnut (Kearney, Oldewage-Theron, & Napier, 2011). Although it may not be regarded as a healthy snack, it is very popular and has not received much attention in research. It is also known as *vetkoek* in South Africa (Kearney et al., 2011). It is produced and sold in the streets in South Africa (SA) and goes by different names in the rest of Africa such as *puff puff* and *bofrot* (Onipe, Beswa, & Jideani, 2016). It is a popular food consumed as breakfast and/or lunch across social status. *Magwinya/vetkoek*, *puff puff* and *bofrot* are made from wheat dough (wheat flour, sugar, salt, yeast and water); and absorb oil up to 14 g/100 g (Onipe et al., 2016).

Deep-fat frying is commonly used in domestic and industrial processing of food products due to preference of consumers to texture, appearance and taste of fried products (Abu-Alruz, 2015; Tabibloghamany, Hojjatoleslami, Farhadian, & Ehsandoost, 2013) as well as its quick and convenient cooking method.

Most fried products absorb substantial amount of fat during deep-fat frying (Adedeji & Ngadi, 2010; Mellema, 2003). A number of factors that could influence oil uptake in fried dough include flour type, dough temperature, degree of mixing, temperature of frying, and the amount of fat in the mix, frying time, moisture content (Mellema, 2003; Pokorny, 1998), product surface area and frying oil quality (Mah, 2008). There are measures taken to reduce oil uptake of fried products such as coating with edible films, incorporation of hydrocolloids (Yazdanseta, Tarzi, & Gharachorloo, 2015), proper post-frying oil drainage (Mellema, 2003); and incorporation of dietary fibre and bran in conventional doughnuts (Kim, Chun, Cho, & Park, 2012; Lee, Kim, Kim, & Park, 2008; Onipe et al., 2016; Yadav & Rajan, 2012).

Psyllium husk (*Plantago ovate* L) fibre represents members of the plant genus (*Plantago*) whose seeds are commercially used in mucilage production (Fischer, Nanxiong, Ralph, Anderson, & Marletta, 2004; Verna & Mogra, 2013). Oat (*Avena stiva*) is a unique cereal grain (Butt, Tahir-Nadeem, Khan, Shabir, & Butt, 2008) and its bran is rich in β -glucan –

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a soluble polysaccharide which confers health promoting properties to consumers such as reduction in blood cholesterol levels (Sterna, Zute, Jansone, Brunava, & Kantane, 2015). The β -glucan in OB is also considered to be a suitable fat replacement in foods because it has high water holding capacity (Dhingra, Michael, Rajput, & Patil, 2011).

Obesity and related health problems are often associated with a sedentary lifestyle and frequent consumption of fried and starchy foods (Malhotra et al., 2008). Magwinya is high in fat and there is currently no information in the literature on the criteria for its oil reduction. Therefore the objective of this study was to investigate the effect of oat bran (OB) and psyllium husk fibre (PF) incorporation on oil reduction of *magwinya*.

Materials and method

Materials

The additives: OB and PF were purchased from commercial health food store, while instant yeast (Anchor, Rymco Pty Ltd), bread wheat flour (Premier foods), salt, sugar (Selati), and sunflower oil (Spar), were purchased from a supermarket in South Africa.

Hydration properties

Water holding capacity, water retention capacity and swelling capacity of OB and PF were determined following the method of Onipe, Beswa, and Jideani (2017).

Magwinya production process

Two methods were used namely, modified and traditional methods. Substitution of OB and PF in the wheat flour was done at varying amounts (Table 1). For the traditional method (TM), the ingredients: cake wheat flour (100 g), salt (1 g), sugar (15 g), yeast (1 g), lukewarm water (100 mL), were weighed and mixed manually using hands for 5 min until a homogenous wet sticky dough was formed, fermented at ambient temperature for 45 min. The dough was piped into deep fried in the oil for 5 min at 180°C.

For the modified method (MM), the ingredients: cake wheat flour (100 g), salt (1 g), sugar (15 g), yeast (1 g), lukewarm water (65 mL), were weighed and mixed using electronic mixer (Russell Hobbs RHSB237 South Africa) for 5 min, fermented in the proofer for 45 min at 27°C. The dough was cut into 50 g, moulded into a ball and fried for 3 min at 180°C (Onipe et al., 2016).

Table 1. One-factor experimental design for oat bran and psyllium husk fibre for *magwinya* production.

Tabla 1. Diseño experimental de un factor para el salvado de avena y la fibra de cáscara de psilio en la producción de *magwinya*.

Runs	Oat bran	Psyllium husk fibre
1	0.34	0.17
2	2.00	1.00
3	6.00	3.00
4	10.00	5.00
5	11.66	5.28

Texture determination

Magwinya samples were tested for hardness following the method described by Kim et al. (2012) with slight modifications using a TA-XT plus texture analyser (Stable Micro Systems Ltd, Godalming, UK) fitted with a 5 kg load cell. Samples cooled at room temperature for 30 min were subjected to return-to-start tests at 40% strain using a 25 mm cylindrical probe (P/26) at 2 mm/s test speed. Hardness was recorded as the peak point in the force-deformation curve. Experiment was repeated three times.

Determination of colour, moisture fat and ash

A Colourflex Spectrophotometer (Hunter Associates Laboratory, Reston, VA., USA) was used for colour analysis of samples. The instrument was standardized with a white and black ceramic plate as indicated by the manufacturer. The L* (Lightness), a* (redness), and b* (yellowness) values were determined as the average of three replicates per production (Onipe et al., 2016).

Moisture fat and ash contents were determined using approved methods 44–15, 30–25.01 and 08–01.01 of AACC (2000).

Optimization procedure and statistical analysis

One factor of the response surface methodology was used to design the experiment in order to determine the effect of each additive on oil uptake reduction of *magwinya*. The ranges of OB and PF in grams were 0–10 and 0–5, respectively. Five runs were generated as shown in Table 1. Results of hydration properties were subjected to a one-way analysis of variance (ANOVA) and Duncan's multiple range test was used to determine the significant differences between treatment means were 95% significance level (Duncan, 1955) using Statistical Package for the Social Sciences version 23. Design Expert statistical software version 8.0.6 was used to calculate regression analysis of the experimental data in order to examine the strength of the relationship between the independent and dependent variables. The influence of OB and PF on oil uptake was determined using the *p*-value obtained from the ANOVA. The adequacy of each model was determined by its Coefficient of determination (R^2). Predictive models of quality parameters or response variables (moisture, ash and fat) were employed to obtain individual desirability.

Results and discussion

Hydration properties

Hydration properties of OB and PF showed significant difference except for WHC (Table 2). The WRC and SC of PF was significantly higher than OB swelling capacity. The SC of 12.27 mL/g was reported compared for PF and OB at 5.03 mL/g. Water retention capacity ranged from 1.60 mL/g to 4.00 mL/g, with PF having the highest WRC. Water holding capacity ranged from 3.83 mL/g to 3.93 mL/g. with OB having the highest value, although the values were not statistically different ($p < 0.05$). The WHC reported in this study was not in agreement with the study of Czuchajowska, Paszczynska, and Pomeranz (1992) at 35.6 g/g WHC of PF. Hydration properties

Table 2. Hydration properties of oat bran and psyllium husk fibre.

Tabla 2. Propiedades hidratantes del salvado de avena y la fibra de cáscara de psilio.

Hydration properties	Oat bran	Psyllium husk fibre
SC (mL/g)	5.03 ± 0.15 ^a	12.27 ± 0.55 ^b
WRC (g/g)	1.60 ± 0.10 ^a	4.00 ± 1.17 ^b
WHC (g/g)	3.93 ± 1.50 ^a	3.83 ± 0.20 ^a

Mean scores in the same row with different superscripts are significantly different ($p < 0.05$).

SC: swelling capacity; WRC: water retention capacity; WHC: water holding capacity.

Las medias en la misma fila acompañadas de distintos superíndices son significativamente diferentes ($p < 0,05$).

SC: capacidad de turgencia; WRC: capacidad de retención de agua; WHC: capacidad de absorción de agua.

of cereal bran and dietary fibre can be used to determine the approximate incorporation levels in food for optimum sensory and textural properties (Raghavendra, Rastogi, Raghavarao, & Tharanathan, 2004). The higher SC of PF can be attributed to its gel-forming property known as mucilage (Verna & Mogra, 2013). It was reported by Inglett and Chen (2012) that OB has higher water holding or binding capacity due to its β -glucan properties. OB showed similar results for both WRC and SC – 5.03 mL/g for OB was in close agreement with 5.53 mL/g (Guillon & Champ, 2000). The main reason for these differences in the hydration values is the difference in the type of dietary fibre and amount of carbohydrates (Guillon & Champ, 2000).

Moisture content of magwinya

The moisture content of OB modified *magwinya* (OBM) ranged from 33.82 to 35.98% and OB traditional *magwinya* (OBT) ranged from 37.43 to 37.73%. Addition of OB significantly increased ($p < 0.05$) moisture contents of both traditional and modified *magwinya*. OBT had higher moisture content than OBM (Figure 1a). The moisture content of psyllium husk fibre-modified *magwinya* (PFM) ranged from 29.31 to 40.61% and psyllium husk fibre traditional *magwinya* (PFT) from 37.25 to 43.41% (Figure 1b). All test samples had significantly higher moisture values than control samples for traditional (32.01%) and modified (27.95%). It has been reported that OB contains excellent moisture retention properties which keeps fried foods fresh with extended shelf life, as a result of β -glucan content of OB which is a soluble polysaccharides (Kaur, Sharma, Nargi, & Dar, 2012). Furthermore, the high moisture content of PF *magwinya* may be explained to be the effect of gum-like structure called mucilage which has higher swelling and higher water absorption capacity (Verna & Mogra, 2013). Comparing the methods, the traditional *magwinya* had higher moisture content than modified *magwinya*; and this is basically due to the higher amount of water (100 mL) added during preparation. Incorporation of PF in *magwinya* showed higher moisture content than the use of OB; and this might be attributable to the higher water retention capacity of PF as discussed in the hydration properties section.

Fat content of magwinya

The effect of OB and PF incorporation was significant in reducing the fat content of *magwinya* when compared to the control samples (12.00% for traditional and 8.89% for

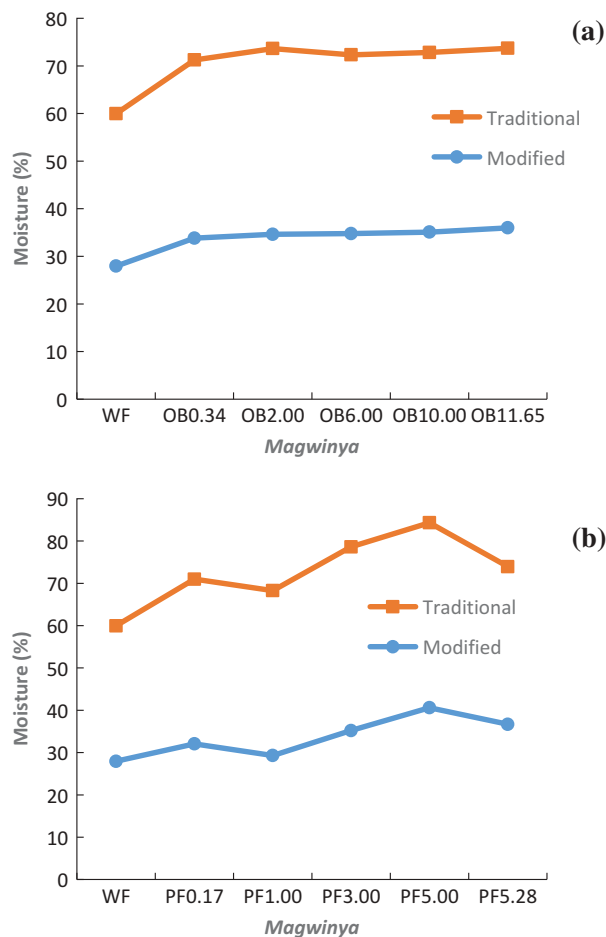


Figure 1. Moisture content of *magwinya* with (a) oat bran and (b) psyllium husk fibre. WF – *magwinya* made with 100% wheat flour while OB 0.34, 2, 6, 10 and 11.65 and PF 0.17, 1, 3, 5 and 5.28 represents amount of oat bran and psyllium husk fibre in substituted in 100 g wheat flour for *magwinya* production.

Figura 1. Contenido de humedad en *magwinya* con (a) salvado de avena y (b) fibra de cáscara de psilio. WF – *magwinya* hecha con 100% harina de trigo; OB de 0,34, 2, 6, 10 y 11,65 y PF de 0,17, 1, 3, 5 y 5,28 representan la cantidad de salvado de avena y fibra de cáscara de psilio sustituidas en 100 g de harina de trigo para la producción de *magwinya*.

modified *magwinya*). The fat content of OBM ranged from 4.35 to 5.05% for the test samples; while OBT ranged from 6.00 to 8.90% (Figure 2a). Lowest fat content for OBM and OBT were recorded at 10 and 2% OB addition, respectively. The fat content of PFM and PFT ranged from 3.10 to 4.80% and 5.50 to 8.55%, respectively (Figure 2b). Lowest fat content for PFM and PFT were recorded at 5.28% and 1% PF addition, respectively. The fat content of traditional *magwinya* was generally higher than modified, and the reason for this may be the longer frying time of 5 min for traditional method, which gave enough time for oil to replace the moisture which escaped in form of steam from the food surface (Mellema, 2003). Another reason may be attributed to porous structure of the *magwinya* which could facilitate mass transfer in the product. This shows that fat content, to an extent is greatly dependent on the frying time and moisture content as modified *magwinya* had lower fat content than traditional *magwinya* for both OB and PF.

The oil reduction effect of PF may be due to mucilage found in PF, which forms a gel and is able to retain significant amount of moisture and prevent the uptake of fat (Czuchajowska et al., 1992). It has been reported by

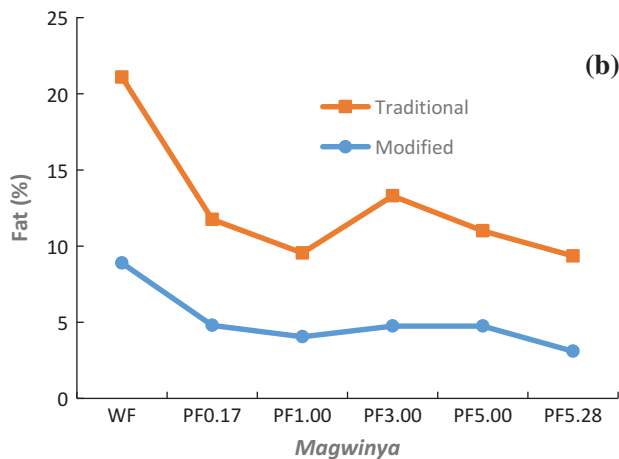
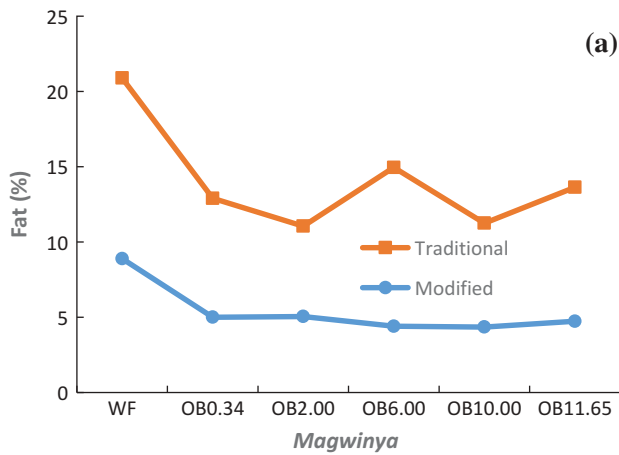


Figure 2. Fat content of *magwinya* with (a) oat bran and (b) psyllium husk fibre. WF – *magwinya* made with 100% wheat flour while OB 0.34, 2, 6, 10 and 11.65 and PF 0.17, 1, 3, 5 and 5.28 represents amount of oat bran and psyllium husk fibre in substituted in 100 g wheat flour for *magwinya* production.

Figura 2. Contenido de ceniza en *magwinya* con (a) salvado de avena y (b) fibra de cáscara de psilio. WF – *magwinya* hecha con 100% harina de trigo; OB de 0,34, 2, 6, 10 y 11,65 y PF de 0,17, 1, 3, 5 y 5,28 representan la cantidad de salvado de avena y fibra de cáscara de psilio sustituidas en 100 g de harina de trigo para la producción de *magwinya*.

Mellema (2003) that oil uptake was related to the adhesion of oil of the fried products after being removed from the frying oil. Higher fat content of traditional control *magwinya* showed that oil absorption may, to a large extent depend on the initial moisture content of the food prior to frying (Southern, Cochen, Farid, Howard, & Eyre, 2000). Reduction of fat content by incorporation of OB can be attributed to its β -glucan content. As reported by Dhingra et al. (2011), OB significantly reduced fat content of pork sausage during frying. Utilization of up to 11 g/100 g wheat flour of OB in a fried flat dough reduced oil uptake up to 20% (Yadav & Rajan, 2012). The β -glucan reduces oil absorption of batters during frying by approximately 20% (Lee & Inglett, 2007). Incorporation and or coating of food products with high fibre additives have led to the development and advancement in market for fibre-rich food products and ingredients (Dhingra et al., 2011; Elleuch et al., 2011).

Ash content of *magwinya*

The ash content of OBM ranged from 0.98 to 2.22% and there was significant difference ($p < 0.05$) among the

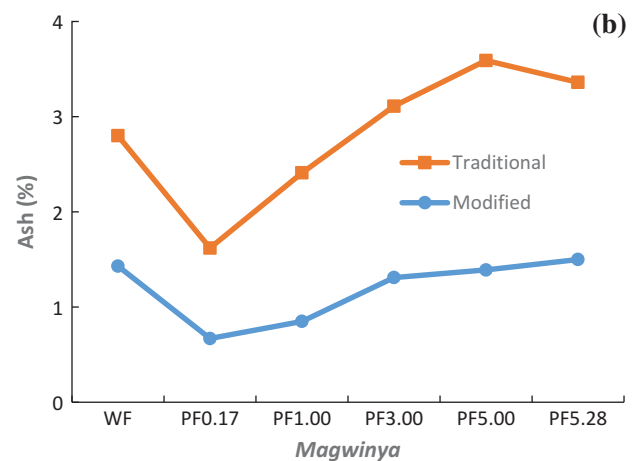
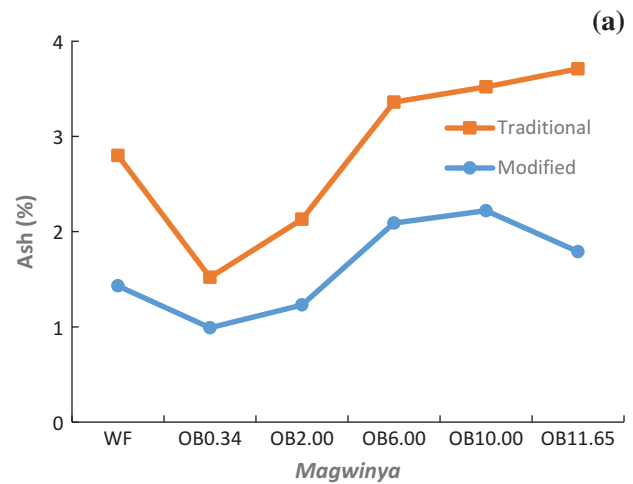


Figure 3. Ash content of *magwinya* with (a) oat bran and (b) psyllium husk fibre. WF – *magwinya* made with 100% wheat flour while OB 0.34, 2, 6, 10 and 11.65 and PF 0.17, 1, 3, 5 and 5.28 represents amount of oat bran and psyllium husk fibre in substituted in 100 g wheat flour for *magwinya* production.

Figura 3. Contenido de grasa en *magwinya* con (a) salvado de avena y (b) fibra de cáscara de psilio. WF – *magwinya* hecha con 100% harina de trigo; OB de 0,34, 2, 6, 10 y 11,65 y PF de 0,17, 1, 3, 5 y 5,28 representan la cantidad de salvado de avena y fibra de cáscara de psilio sustituidas en 100 g de harina de trigo para la producción de *magwinya*.

treatments and the control sample; while the ash values of OBT increased from 0.53 to 1.92% with incremental addition of OB (Figure 3a). This same trend was observed in PFM ash values which ranged from 0.67 to 1.50% while PFT ranged from 0.95 to 2.20% (Figure 3b). Incorporation of OB and PF increased ash content of *magwinya* as a result of the nutrients condensed in the bran and husk consequentially increasing ash content of *magwinya*.

Hardness of *magwinya*

Hardness of OBM, OBT, PFM, and PFT ranged from 2037.67 to 2080 g, 709.23 to 1384.36 g, 1171.60 to 1996.26 g and 1058.63 1104.96 g, respectively. The hardness values for OBM were not statistically different from each other but significantly higher ($p < 0.05$) than the control sample. Least OBT hardness was 709.23 g at 0.34 g OB incorporation. OBT test samples were significantly different from the control with the exception of 2.00 and 6.00 g OBM. All test samples for PFM were significantly different ($p < 0.05$) from the control. Incorporation up to 3% for PF and 2% OB had less hardness compared to the control. Hardness

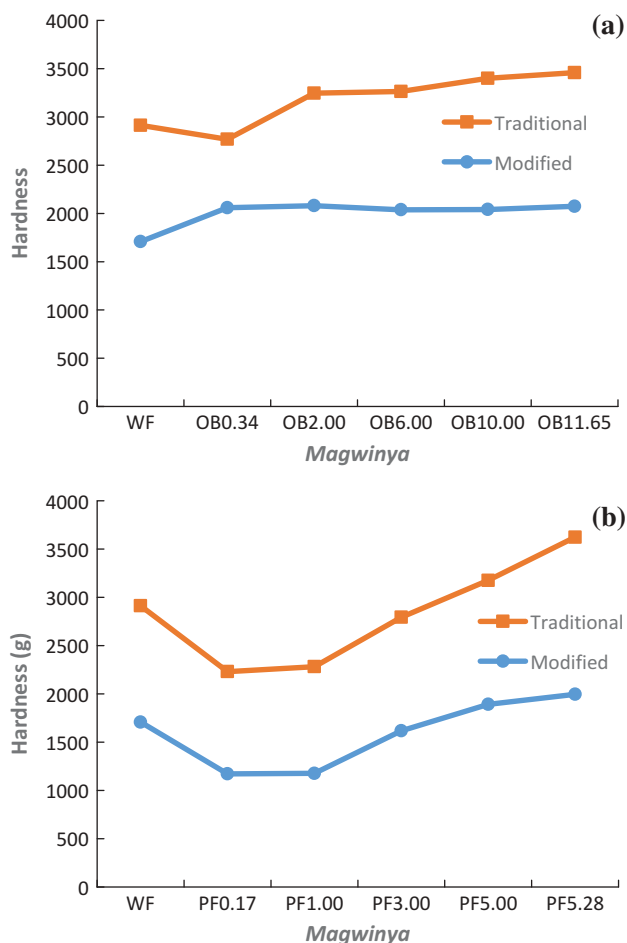


Figure 4. Hardness of *magwinya* with (a) oat bran and (b) psyllium husk fibre. WF – *magwinya* made with 100% wheat flour while OB 0.34, 2, 6, 10 and 11.65 and PF 0.17, 1, 3, 5 and 5.28 represents amount of oat bran and psyllium husk fibre in substituted in 100 g wheat flour for *magwinya* production.

Figura 4. Dureza de *magwinya* con (a) salvado de avena y (b) fibra de cáscara de psilio. WF – *magwinya* hecha con 100% harina de trigo; OB de 0,34, 2, 6, 10 y 11,65 y PF de 0,17, 1, 3, 5 y 5,28 representan la cantidad de salvado de avena y fibra de cáscara de psilio sustituida en 100 g de harina de trigo para la producción de *magwinya*.

of all test samples increased as amount of either PF or OB increased. Comparing the methods, hardness of OBM was higher than OBT because of the higher moisture content of OBT which gave a softer product (Figure 4a). The same trend was observed in PFM and PFT (Figure 4b).

The resistance of a product to deformation is referred to as firmness or hardness and it is regarded as a vital component of baked products as it largely contributes to consumer acceptance. (Sabanis, Lebesi, & Tzia, 2009). OBM was found to have higher hardness compared to OBT; this can be attributed to the varying amount of water used in dough preparation – with the former having less water than the latter. As OB increased, hardness also increased for both traditional and modified method. The above results are in agreement with the results obtained by Grigelmo-Miguel, Carreras-Boladeras, and Martin-Belloso (1999) and Majzoobi, Habibi, Hedayati, and Farahnaky (2015). It was reported by Majzoobi et al. (2015) that moisture and interactions between oat fibre and ingredients used during preparation have an effect on the hardness. As reported by Feili, Abdullah, and Yang (2013), hardness is largely attributed to amylase and amylopectin matrix and also due to interaction between gluten and fibrous materials.

Colour properties of *magwinya*

A vital characteristic for baked and fried products which largely contributes to consumer acceptance is colour. It depends on physicochemical characteristics of the dough such as water activity, reducing sugar, pH, and amino acids as well as other processing parameters during frying such as temperature (Sabanis et al., 2009). Measurements of colour properties of OB/PF *magwinya* were conducted on both crust and crumb. Comparison of crumb and crust colour properties (L^* , a^* , and b^*) for OBM, OBT, PFM and PFT showed significant difference between the test samples and the control. Crust lightness of OBM, OBT, PFM and PFT ranged from 35.26 to 50.32, 32.30 to 53.26 (Table 3), 34.11 to 47.97 and 25.02 to 51.97 (Table 4), respectively; and were all significantly higher than the control. Significant difference ($p < 0.05$) existed among test samples and the control for OBM, OBT, PFM and PFT. Incorporation of OB and PF significantly increased the lightness of *magwinya* samples. Lightness of OBM was higher than OBT and could be attributed to shorter frying time of 3 min. In comparison to the control samples, there was an increase in crust redness (a^* values) of OBM, OBT and PFM while a decrease was recorded for PFT. On the other hand, yellowness (b^* values) increased in OBM, OBT, PFM and PFT. The increase in crust yellowness and decrease in redness was also reported by Majzoobi (2015). Crust colour can be attributed to Maillard reaction and caramelization which occurred as a result of frying at 180°C (Pathare, Opara, & Al-Said, 2013).

Crumb colour

Crumb lightness values of OBM, OBT, PFM and PFT ranged from 52.90 to 65.65, 63.84 to 69.34, 51.27 to 65.86 and 42.53 to 65.03, respectively. As reported for crust colour, lightness, redness and yellowness of all samples were significantly higher than the control samples which indicated that OB and PF increased the colour parameters. Crumb colour of products processed at high temperature (like baked and fried products) depends on the ingredients such as the colour of dietary fibre or cereal bran (Almeida, Chang, & Steel, 2013). Processing conditions such as time and temperature used during frying do not have an effect on the crumb colour because an increase in temperature does not give Maillard reaction or caramelization process. Reduction of crumb lightness is strongly related to effect of the fibre source on crumb moisture as the higher the moisture, the lower the lightness. It was observed that when the percentage of OB/PF was added increased, crumb lightness (L^* values) and redness (a^* values) decreased, while yellowness (b^* values) increased for all the samples. Similar observation was reported by Majzoobi et al. (2015).

Interpretation of regression model of quality parameters

The regression model representing the effect of OB and PF addition on *magwinya* samples is presented in Tables 5 and 6. Linear, quadratic and cubic models were presented for the responses. Coefficient of determination (R^2) was used to determine the adequacy of the models. For OBM, relatively higher R^2 values were obtained for more than half of the responses when compared to OBT. R^2 values of 0.90, 0.93, 0.94, 0.94, 0.63, 0.80 and 0.94 were adequate to describe the fitness of models for moisture, ash, hardness, crumb redness,

Table 3. Colour properties of *magwinya* with oat bran.Tabla 3. Propiedades de color de la *magwinya* hecha con salvado de avena.

Samples	Modified					
	Crust			Crumb		
	L*	a*	b*	L*	a*	b*
WF	26.26 ± 0.05 ^a	12.74 ± 0.07 ^{bc}	20.21 ± 0.01 ^a	47.31 ± 0.02 ^a	1.89 ± 0.01 ^a	17.28 ± 0.02 ^a
OB0.34	49.31 ± 0.01 ^e	6.50 ± 0.01 ^a	23.33 ± 0.03 ^b	63.51 ± 0.51 ^e	3.09 ± 0.01 ^d	23.10 ± 0.01 ^{ab}
OB2.0	50.32 ± 0.01 ^f	16.92 ± 0.0 ^{cd}	34.55 ± 0.02 ^c	65.65 ± 0.57 ^d	1.89 ± 0.35 ^a	21.91 ± 0.04 ^{bc}
OB6.0	47.16 ± 0.18 ^d	12.19 ± 0.17 ^b	29.84 ± 0.11 ^d	63.49 ± 0.43 ^d	2.75 ± 0.15 ^c	22.61 ± 0.02 ^{bc}
OB10.0	46.63 ± 0.03 ^c	16.83 ± 2.75 ^d	33.30 ± 0.01 ^e	52.90 ± 0.01 ^c	2.44 ± 0.00 ^b	20.31 ± 0.21 ^{bc}
OB11.65	35.26 ± 0.03 ^b	16.57 ± 0.01 ^{bcd}	26.47 ± 0.02 ^f	53.84 ± 0.01 ^b	2.33 ± 0.01 ^b	19.20 ± 0.05 ^{ab}
Traditional						
WF	15.87 ± 0.04 ^a	10.27 ± 0.15 ^b	11.69 ± 0.01 ^a	55.71 ± 0.12 ^a	0.64 ± 0.01 ^a	13.21 ± 0.58 ^a
OB0.34	53.26 ± 0.16 ^f	11.29 ± 0.04 ^b	24.19 ± 0.12 ^c	69.34 ± 0.01 ^e	1.68 ± 0.01 ^b	22.43 ± 0.04 ^b
OB2.0	36.91 ± 0.76 ^e	17.81 ± 0.44 ^c	25.29 ± 1.06 ^d	69.33 ± 0.30 ^f	1.33 ± 0.01 ^b	22.66 ± 0.05 ^b
OB6.0	36.17 ± 0.03 ^d	13.09 ± 7.78 ^a	19.50 ± 0.60 ^b	68.01 ± 0.07 ^d	1.43 ± 0.01 ^b	22.71 ± 0.04 ^b
OB10.0	35.63 ± 0.06 ^c	17.79 ± 0.03 ^c	24.75 ± 0.11 ^{cd}	64.78 ± 0.53 ^c	2.47 ± 0.51 ^c	22.77 ± 1.92 ^b
OB11.65	32.30 ± 0.10 ^b	16.56 ± 0.04 ^c	30.29 ± 0.22 ^e	63.84 ± 0.02 ^b	3.09 ± 0.01 ^d	24.82 ± 0.04 ^c

Mean scores in the same column with different superscripts are significantly different ($p < 0.05$). L*: lightness; a*: redness; b*: yellowness; WF: *magwinya* made with 100% wheat flour while OB 0.34, 2, 6, 10 and 11.65 represents amount of oat bran substituted with wheat flour for *magwinya* production.

Las medias en la misma columna acompañadas de superíndices diferentes son estadísticamente diferentes ($p < 0.05$). L*: liviandad; a*: rojez; b*: amarillez; WF: *magwinya* hecha con 100% de harina de trigo; OB 0,34, 2, 6, 10 y 11,65 representan la cantidad de salvado de avena sustituida en lugar de harina de trigo para la producción de *magwinya*.

Table 4. Colour properties of *magwinya* with psyllium husk fibre.Tabla 4. Propiedades de color de *magwinya* hecha con fibra de cáscara de psilio

Sample	Modified					
	Crust			Crumb		
	L*	a*	b*	L*	a*	b*
WF	26.26 ± 0.05 ^a	12.74 ± 0.30 ^b	20.21 ± 0.01 ^a	47.31 ± 0.01 ^a	1.89 ± 0.85 ^a	17.28 ± 0.20 ^a
PF0.17	41.06 ± 0.32 ^b	12.61 ± 0.03 ^a	24.95 ± 0.01 ^b	65.86 ± 0.10 ^f	4.47 ± 0.05 ^e	19.76 ± 0.00 ^b
PF1.00	34.11 ± 1.72 ^{ab}	16.95 ± 0.45 ^e	25.07 ± 0.02 ^c	52.20 ± 0.02 ^c	3.48 ± 0.44 ^c	21.00 ± 0.25 ^d
PF3.00	46.40 ± 0.06 ^b	18.48 ± 0.04 ^f	35.89 ± 0.03 ^e	64.39 ± 0.01 ^e	3.39 ± 0.25 ^b	23.46 ± 0.01 ^f
PF5.00	46.38 ± 0.01 ^b	16.59 ± 0.08 ^d	33.40 ± 0.02 ^f	61.86 ± 0.12 ^d	3.41 ± 0.35 ^b	22.48 ± 0.01 ^e
PF5.28	47.97 ± 0.17 ^b	13.48 ± 0.10 ^c	26.68 ± 0.01 ^d	51.27 ± 0.00 ^b	4.24 ± 0.10 ^d	20.46 ± 0.11 ^c
Traditional						
WF	15.87 ± 0.49 ^a	10.27 ± 0.15 ^e	11.69 ± 0.01 ^a	55.71 ± 0.12 ^a	0.64 ± 0.10 ^a	13.21 ± 0.58 ^a
PF0.17	51.67 ± 0.02 ^e	8.40 ± 0.07 ^b	25.40 ± 0.25 ^f	62.58 ± 0.06 ^a	1.83 ± 0.20 ^b	21.93 ± 0.01 ^e
PF1.00	41.03 ± 0.83 ^d	9.72 ± 0.09 ^d	21.66 ± 0.04 ^e	65.03 ± 2.20 ^a	1.97 ± 0.23 ^c	20.96 ± 0.30 ^d
PF3.00	25.02 ± 1.90 ^b	14.14 ± 0.11 ^f	17.48 ± 0.24 ^d	64.68 ± 0.04 ^a	2.52 ± 0.00 ^d	18.34 ± 0.07 ^c
PF5.00	32.14 ± 0.53 ^c	9.22 ± 0.07 ^c	15.68 ± 0.10 ^c	42.53 ± 3.17 ^a	2.98 ± 0.02 ^e	16.70 ± 0.36 ^b
PF5.28	40.98 ± 0.58 ^d	6.79 ± 0.03 ^a	15.40 ± 0.03 ^b	55.74 ± 0.01 ^a	4.45 ± 0.25 ^f	17.99 ± 0.02 ^c

Mean scores in the same column with different superscripts are significantly different ($p < 0.05$). L*: lightness; a*: redness; b*: yellowness; WF: *magwinya* made with 100% wheat flour while PF 0.17, 1, 3, 5 and 5.28 represents amount of psyllium husk fibre substituted with wheat flour for *magwinya* production.

Las medias en la misma columna acompañadas de superíndices diferentes son estadísticamente significativas ($p < 0.05$). L*: liviandad; a*: rojez; b*: amarillez; WF: *magwinya* hecha con 100% de harina de trigo; PF de 0,17, 1, 3, 5 y 5,28 representan la cantidad de fibra de cáscara de psilio sustituida en lugar de harina de trigo para la producción de *magwinya*.

Table 5. Regression model of quality parameters of modified and traditional *magwinya* with oat bran.Tabla 5. Modelo de regresión de los parámetros de calidad correspondientes a la *magwinya* modificada y tradicional hecha con salvado de avena.

Response	Model equation		R ²	
	Modified	Traditional	Modified	Traditional
Moisture	$34.18 + 5.72 \times A - 0.37 \times A^2 - 4.45 \times A^3$	$37.87 - 0.16 \times A$	0.99	0.07
Ash	$1.73 + 0.58 \times A$	$1.21 - 0.23 \times A$	0.93	0.23
Hardness	$20.48 - 0.53 \times A + 0.048 \times A^2 + 0.36 \times A^3$	$11,646.92 + 1.96 \times A$	0.94	0.60
Colour				
Crust				
L*	$46.22 - 4.42 \times A$	$45.20 - 3.15 \times A$	0.63	0.13
a*	$14.11 + 3.28 \times A$	$13.16 + 1.39 \times A$	0.45	0.05
b*	$29.43 + 0.60 \times A$	$20 + 0.51 \times A + 4.61 \times A^2$	0.01	0.81
Crumb				
L*	$60.43 - 4.96 \times A$	$68.43 - 3.35 \times A - 1.21 \times A^2 + 0.68 \times A^3$	0.80	0.99
a*	$2.51 + 0.099 \times A$	$1.36 + 0.58 \times A + 0.64 \times A^2 - 0.696 \times A^3$	0.05	1.00
b*	$22.69 + 3.33 \times A - 0.11 \times A^2 - 3.05 \times A^3$	$22.54 - 1.07 \times A + 0.23 \times A^2 + 1.17 \times A^3$	0.94	0.91
Fat	$4.93 - 0.20 \times A$	$8 + 0.43 \times A$	0.30	0.07

L*: lightness; a* : redness; b* : yellowness; A: oat bran.

L*: Liviandad; a*: rojez; b*: amarillez; A: salvado de avena.

crust and crumb lightness. On the other hand, R^2 values lower than 0.5 implies that the models is not suitable in predicting the responses. On the other hand, the R^2 values

for PFM and PFT were higher ranging from 0.47 to 0.99 (Table 6). This implies that the effect of PF on *magwinya* was significant to generate fit models that can predict the

Table 6. Regression model of quality parameters of modified and traditional *magwinya* with psyllium husk fibre.

Tabla 6. Modelo de regresión de los parámetros de calidad correspondientes a la *magwinya* modificada y tradicional hecha con fibra de cáscara de psilio.

Responses	Model equation		R^2	
	Modified	Traditional	Modified	Traditional
Moisture	$35.30 + 9.66 \times B - 0.43 \times B^2 - 4.02 \times B^3$	$42.30 - 0.38 \times B - 2.47 \times B^2$	0.99	0.69
Ash	$0.68 - 0.42 \times B + 0.39B^2 + 0.19 \times B^3$	$2.02 + 0.31 \times B - 0.28 \times B^2$	0.99	0.91
Hardness	$1042.55 - 89.63 \times B + 162.05 \times B^2$	$1042.55 - 88.61 \times B + 1733.04 \times B^2$	0.81	0.63
Colour	L* $44.97 + 11.89 \times B - 2.28 \times B^2 - 5.75 \times B^3$	$25.54 - 4.00 \times B + 10.52 \times B^2$	0.93	0.99
Crust				
Crumb	a*	$19.05 + 0.15 \times B - 2.86 \times B^2$	0.80	0.92
	b*	$34.97 + 1.80 \times B - 4.81 \times B^2$	0.88	0.99
	L*	$61.85 + 14.82 \times B - 2.28 \times B^2 - 9.99B^3$	0.80	0.47
	a*	$3.15 - 0.067 \times B + 0.54 \times B^2$	0.99	0.83
Fat	b*	$23.44 + 1.23 \times B - 1.67 \times B^2 - 0.49 \times B^3$	0.99	0.84
		$4.82 - 1.28 \times B - 0.44 \times B^2 + 0.93B^3$	0.99	0.96

L*: lightness; a*: redness; b*: yellowness; B: psyllium husk fibre.

L*: liviandad; a*: rojez; b*: amarillez; B: fibra de cáscara de psilio.

Table 7. Numerical optimization of quality parameters of traditional and modified *magwinya* with oat bran and psyllium husk fibre.

Tabla 7. Optimización numérica de los parámetros de calidad de la *magwinya* tradicional y modificada con salvado de avena y fibra de cáscara de psilio.

Samples	OB/PF amount (g)	Moisture (%)	Ash (%)	Fat (%)	Desirability
OBM	10.00	35.08	2.31	4.74	0.83
OBT	1.11	38.03	1.43	7.58	0.56
PFM	5.00	40.52	0.84	4.03	0.45
PFT	4.07	41.40	2.10	5.68	0.82

OB: oat bran; PF: psyllium husk fibre; OBM: OB modified *magwinya*; OBT: OB traditional *magwinya*; PFM: PF modified *magwinya*; PFT: PF traditional *magwinya*.

OB: salvado de avena; PF: fibra de cáscara de psilio; OBM: OB *magwinya* modificada; OBT: OB *magwinya* tradicional; PFM: PF *magwinya* modificada; PFT: PF *magwinya* tradicional.

responses for *magwinya* with the exception of the lowest value of 0.47 reported for crumb lightness of PFT.

Numerical optimization

Responses taken into consideration for optimization of level of variables were moisture, ash and fat contents. These responses had critical role in judging the quality of OB and PF as determined by their respective R^2 values (Tables 5 and 6). The desired goals for each factor and response was inputted and the solution with maximum desirability was selected as optimum formulation. The goals were minimum/reduced fat content and maximum ash and moisture contents. The result are presented in Table 7. The optimal conditions observed for OBM were moisture, ash and fat were 35.08, 2.31, 4.73% at 10.00 g OB incorporation, with desirability at 0.828. Optimal condition for PFT was observed at 4.07 g PF addition, with moisture content of 41.40%, ash (2.10%), fat (5.68%) at desirability at 0.82. PF and OB can used for incorporation in frying of *magwinya*

Conclusion

The hydration properties of OB and PF and the effect of their incorporation on some quality parameters (hardness, colour, moisture, fat, ash) of *magwinya* – a cereal fried dough showed that of the two additives, PF significantly reduced fat content better than OB. The modified method of frying gave better *magwinya* in terms of reducing fat content

compared to traditional method. Traditional method much more reduced the hardness of *magwinya*, which was also shown in moisture content. In general, incorporation of OB and PF in traditional *magwinya* cereal snack reduced oil content, increased total mineral content (ash), reduced hardness and lightness. Sensory properties of OB/PF *magwinya* may be essential in evaluating the response of consumers to these additives.

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