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CHEMICAL AND FUNCTIONAL PROPERTIES OF SNACKS PRODUCED FROM WHEAT FLOUR FORTIFIED WITH *Moringa oleifera* LEAF POWDER

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ABSTRACT

Healthy snacks are widely accepted and can be part of a daily diet since they can be eaten in different areas such as homes, offices, conferences, workshops, and most especially in schools. Snacks have become an essential commodity in every home for both young and old. There are several reasons why snacks are consumed. It could result from hunger, convenience, cravings, socializing, and emotional comfort. Various individual, societal, and environmental elements influence snacking behaviour. Furthermore, awareness of healthy snacks and self-esteem in selecting the "right" snacks are major predictors of snacking behaviour. Most snack foods are commonly referred to as "junk food" or "empty foods" because they include a large amount of calories from sugar or fat with minimal protein, vitamin, or mineral content. However, despite their role in the daily diet, these snacks are mostly energy dense and low in nutrients. Some research studies have been done on functional snacks, but more is yet to be explored. *Moringa oleifera* leaf powder (MoLP) has been helpful as a food fortificant in various products. This study has utilized it to fortify two varieties of snacks, namely *Magwinya* and *Chinchin* (wheat flour). The chemical and functional properties of these snack food products after fortification with MoLP at 0% (Control), 1% and 5% of the variants were determined. *Moringa oleifera* leaf powder (MoLP) (1% and 5%) had a significant ($p \leq 0.05$) effect on the moisture (4.63 – 3.97%), ash (0.52 - 1.09%), protein (11.36 – 13.40%), and total fat of both the dough (0.17 – 0.81%) and fried product (10.17 – 15.39%) of *Magwinya* samples. *Chinchin* fortified with MoLP had a significantly ($p < 0.05$) higher phenolic content (1.08 – 2.17 mg GAE/g), antioxidant activity (13.41 – 53.81 µmol TE/g), protein content (6.27 - 6.74%), oil uptake (1.89 - 7.12%), and ash (0.99 - 1.39%) consistently at 5% MoLP. These results show that these snacks fortified by MoLP can be advantageous to children and adults in Western and Southern Africa.

Key words: *Moringa oleifera* Leaf Powder (MoLP), Wheat flour, Fortification, Chemical, Functional

INTRODUCTION

Different scholars [1, 2, 3] have highlighted that *Magwinya* is a traditional snack native to Southern Africa. Magwinya, sometimes referred to as "fat cakes," is a typical deep-fried doughnut-like bread or cake made from flour. Although it might not be thought of as a nutritious food, it is very well-liked and little research has been done on it [1]. *Chinchin* is a popular wheat-based deep-fried snack commonly consumed in Nigeria and other West African countries, even though it is relatively unknown in South Africa. Although the consumption of *Chinchin* snacks was previously limited to the area of production, there seems to be an increasing demand for its consumption in other countries in Africa. For instance, the *Chinchin* snack is now being sold in different supermarkets in Nigeria after value addition through flavouring ingredients, better packaging, and fortification with high protein plant-based crops [4]. Food fortification is a required method that has gone a long way to combat and reduce micronutrient deficiencies. Adding minerals and vitamins to staple foods ensures more people access essential nutrients without changing their food consumption behaviour [4]. It can be done through fortification, which involves the incorporation of macro or micronutrients to improve the nutritional quality of foodstuff. Foods generally fortified are wheat flour or wheat flour-based foods with synthetic or natural micronutrients derived from fruits or berries. Generally, when food is fortified, the fortificant provides limited functionality. However, the demand for ingredients whose single use provides many functions is on the increase [4].

Moringa oleifera (Lam.) is a crop native to the Northern Indian regions, although it is found and cultivated in other parts of Asia and Africa [5]. Parts of the Moringa tree are well known to be rich in micro and macronutrients and have been used as "natural" medicine for years. *Moringa oleifera* leaf powder (MoLP) is a good source of minerals such as calcium, potassium, zinc, magnesium, iron and copper, vitamins such as vitamin A, folic acid, vitamin C, D, and E, antioxidants, essential amino acids and of protein [6]. Given its nutrient richness, *Moringa oleifera* leaf powder (MoLP) serves as a food fortificant in a wide variety of products, including bread, biscuits, maize gruel, stiff dough, soups, beverages, yoghurts, cheese, and beef bouillon, and was found to positively contribute to the improvement in the nutritional value of foods fortified [6].

Snacks have gained wide popularity in the office space, at conferences, in homes, and most especially in schools, where they can be bought at “tuckshops” (a store, usually on school grounds, that sells candy, snacks, and soft beverages). This has, however, given rise to an increase in obesity in children and adolescents. For

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example, in a study by Abrahams *et al.* [7], it was observed that, on average, children and adolescents from disadvantaged schools in the Western Cape who consumed snacks purchased from the tuckshops rather than home-cooked or made lunches had significantly higher BMI's than those who had homemade lunches and had a significantly less varied diet. An example of a popular and relatively affordable lunch item that could be purchased from these tuckshops would be *Magwinya* (also known as vetkoek), a deep-fried sweet or savoury dough. Even though *Magwinya* is very high in carbohydrates and fat from the frying oil, adding a healthy ingredient may improve its nutritional content, allowing for a combination of the appeal and affordability of *Magwinya* and the benefits of something more nutritious. A possible component that could enrich this foodstuff would be *Moringa oleifera*, a plant with leaves that are exceptionally high in protein, antioxidants and numerous vitamins and minerals [8]. However, one of the most noteworthy characteristics of this *Moringa oleifera* leaves that makes them excellent as a fortificant for a snack like *Magwinya* would be their capacity to manage obesity, particularly the obesity created by a high-fat diet [8].

Similar nutritionally low-value and high-energy snacks have increased in South Africa and are also commonly consumed as a meal. Chinchin, a Western African snack food made from wheat flour, margarine, evaporated milk, baking powder, sugar and eggs and commonly flavoured with ground nutmeg, is now relatively known in South Africa and comes in a variety of shapes and sizes. Due to its high carbohydrate composition and energy density, *Chinchin* is often consumed as a substitute meal, particularly by children and adolescents. The popularity of *Chinchin* in Nigeria and its obscurity in Southern Africa make it a candidate snack food to introduce into the market. However, its low nutrient content [9] must be improved to compete with other snack foods on the market. Therefore, this study aims to look at the effect of fortifying these snack foods identified above (*Magwinya* and Chinchin) with Moringa leaf powder (MoLP), with the emphasis being on their chemical and functional properties.

MATERIALS AND METHODS

Materials

The materials used in the experiment consisted of wheat flour, white sugar, instant yeast, table salt, margarine, full cream milk, salt, baking powder, nutmeg and canola oil from checkers mall, Cape Town. *Moringa oleifera* leaf powder was purchased from SupaNutri Pty Ltd, Graaf-Reinet RSA. The chemicals used in this study were of analytical grade (Sigma-Aldrich, Johannesburg, South Africa). The equipment used is available at the Department of Food Technology and Oxidative

Stress Research Centre of the Cape Peninsula University of Technology, Cape Town.

Formulation of blends

Wheat flour and MoLP were mixed at different proportions; 100%:0%, 99%:1%, 95%:5%, respectively. A mixer (Russell Hobbs RHSB237, South Africa) was used for mixing the samples to achieve uniform blends.

Preparation of *Magwinya*

Magwinya snack was prepared by modifying the method described by Akubor [2]. In the making of this snack food, different ingredients, (see Table 1) namely wheat flour, white sugar, instant yeast, table salt, MoLP, oil and water, were weighed and mixed in a mixer manually for 5 min to obtain a homogenous wet sticky dough compared to what the previous author did by first mixing thoroughly the dry ingredients for 60 s by hand. The dough was kneaded for 10 min in a mixer (Russell Hobbs RHSB237, South Africa) and placed in a Macadam proofer (2250 by 1000 mm in size) for 1 h. Afterwards, a small portion of the dough was scooped out and dropped into a deep fryer (Russell Hobbs RDF300, South Africa) at 190 °C. *Magwinya* was placed on an absorbent paper to absorb excess oil and allowed to cool down to ambient temperature. This was repeated for the other two concentrations of MoLP (1% and 5%).

Production of Chinchin

The method of Adebayo-Oyetoro *et al.* [10] was used with some adjustments. Wheat flour and Moringa blends were produced in 400 g batches by combining wheat flour with MoLP at varying ratios (100:0, 99:1, 95:5) (see Table 2). The flour blends, sugar, salt, baking powder and nutmeg were sifted into the Kenwood (KM010) mixer bowl and mixed by the k-beater attachment before adding the cooled margarine and mixing on low speed for 4 minutes as opposed the author's method that was manually mixed. The k-beater was later exchanged by the dough hook attachment, turned on low speed, and the milk and eggs were then added to the mixture. The dough was mixed on medium speed for five minutes before resting at 5 °C for 30 minutes. The dough was then rolled and passed through a pastry sheet until it had a thickness of 3 mm before being cut into strips of 8 cm in length and 1 cm in width. Approximately 158 g of the strips were deep fried in 2 L of canola oil at 170 °C for 1 minute and 20 seconds on each side in a Sunbeam (SDF-8502B) 3 L deep fryer. The *Chinchin* was then cooled and stored at room temperature, and dough samples were kept at 4 °C until they get analysed.

Analyses

Chemical analysis of *Moringa oleifera* leaf powder and the snack food products

Moringa oleifera leaf powder (MoLP) and snack samples were analysed according to AOAC Method 934.01 [7] for moisture content and determined by a moisture analyzer and Soxhlet method for crude fat extraction. The nitrogen content was determined using the Kjeldahl method, and ash was determined gravimetrically. Total carbohydrate (TC) was calculated by difference (TC%) = 100 − (moisture + protein + fat + ash) [8].

Colour parameters of snack food products

The most popular methods for measuring the colour of various food products employ instruments that measure the surface reflectance of the food. The CIELAB coordinates L∗, a∗, and b∗ have been successfully used to describe food and beverage colours [11]. The L∗, a∗, and b∗ values explain a 3-dimensional colour space. The beverage and snack samples' CIE colour values (L*, a* and b*) were determined using the pre-calibrated Hunter Lab colour flex spectrophotometer. Before measuring the colour of the samples, the instrument was standardised by placing black and white standard plates, and L*, a* and b* colour values were recorded. The deviation of the colour of the samples to the standard was observed and recorded. L* values correspond to lightness/darkness and range from 0 (black) to 100 (white), with higher values corresponding to more lightness, whereas a* and b* values correspond to an object's colour dimensions, with a* values describing a sample's redness (+a) to greenness (-a), and b* values describing a sample's yellowness (+b) to blueness (-b). Note that higher a* values indicate more redness, while higher b* values indicate more yellowness. The samples (1 g in a sample cup) were measured in triplicate [11].

$$\triangle E:\triangle E^*=[(\triangle L^*)2+(\triangle a^*)2.+(\triangle b^*)2]1/2$$

△ E is calculated by the formula in the international standard colour space L * a * b.

Total Phenolic Content (TPC) and antioxidant activity of snack food products

Total Phenolic Content (TPC) of snack food products

The total concentration of phenol (TPH) within the extracts was determined according to the Folin-Ciocalteu method with Gallic acid (GA) as the standard and was then expressed (mg) as Gallic acid equivalents (GAE) /10 g of extract. 20 µl of sample extract was added to 1.58 ml distilled water, and then 100 µl of Folin-

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Ciocalteu reagent was added. After 1 min, 300 µl of 20% sodium carbonate solution was added. After 2 hours of incubation at room temperature, the resulting blue colour was read at an absorbance of 765 nm. Samples were analysed in triplicate [12]. Total Phenolic Content (TPC) was determined from the calibration curve of Gallic acid.

Oxygen Radical Absorbance Capacity (ORAC) of snack food products

This method determines the antioxidant activity of the samples and is performed using a fluorescence spectrophotometer until zero fluorescence occurs. The results are reported as the ORAC value, which refers to the net protection area under the quenching curve of β-PE (fluorescein) in the presence of an antioxidant. The ORAC value is calculated by dividing the area under the sample curve by the area under the Trolox curve. Both areas are collected by subtracting the area under the blank curve. One ORAC unit is the net protection area provided by one µM Trolox in final concentration. When the area under the curve for the sample is compared to the area under the curve for Trolox, the result is given in Trolox equivalents. The ORAC method is unique in its analysis in that it considers the inhibition time and the degree of inhibition into a single quantity by measuring the area under the curve. The ORAC method is not affected by dilution [13].

Statistical analysis

All analyses were done in triplicates and subjected to analysis of Variance (ANOVA) using IBM® SPSS® statistics version 26, 2018 on the data obtained, whereas Duncan's multiple range tests were used to separate means and significant differences ($p < 0.05$) within the means. Significant differences were defined at ($p \leq 0.05$). The data obtained were recorded as mean values with standard deviation (mean ± standard deviation).

RESULTS AND DISCUSSION

The amount of moisture, fat, ash, and protein, in food snacks (Magwinya, and Chinchin) were determined for chemical and functional purpose. The results of chemical composition of MoLP show an acceptable level for moisture, protein, fat, ash, and carbohydrate contents in Table 3 like the trends reported by [14, 15].

Chemical composition of MoLP

The chemical composition of MoLP is shown in Table 3. The protein and crude fat contents are higher than those found by Olusanya *et al.* [16] and Ilyas *et al.* [17], respectively. Differences in protein and fat contents could be attributed to plant varieties, growing climates, ripening stages, and the extraction methods used.

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Essentially, the high rate of the protein yield clearly indicates that the Moringa leaves have potential utilization in various applications within the food industry. The leaves contained a higher amount of protein (27.96%), which makes it a good and cheap source of protein supplement. An acceptable level of moisture content was present in the leaves after drying and the ash contents also exhibited a similar trend, showing the presence of an appreciable amount of minerals in the leaves.

Chemical composition of Magwinya

As shown in Table 4, the moisture content of the *Magwinya* ranged from (3.97%) to (4.63%). Moisture content was higher in the 0% control (4.63%). These values were significantly ($p < 0.05$) different. Ndife *et al.* [18] reported moisture content (3.18 - 3.54%) for chin-chin from wheat and Cissus populnea stem composite flours. The numbers fell within the range that was said to have no negative impact on the product's quality attribute. The low moisture content exhibited by the *Magwinya* samples indicates that the products will have shelf stability. The ash content of the *Magwinya* samples ranged from (0.52 - 1.09%), and there was a significant difference ($p < 0.05$) in the ash content of those samples. The addition of MoLP at 5% produced higher ash content when compared to the control sample. The ash content is a rough estimate of the mineral contents of foods [18]. Significantly ($p< 0.05$) lower crude protein (11.36%) was recorded within the control sample when compared to the 5% products at (13.40%). The significant ($p< 0.05$) difference existing in the fat uptake between the control sample (10.00%) and the 5% sample (15.58%) indicates that the MoLP has already 7.87% crude fat content. The fat content being somehow higher than anticipated could likely result from the processing of the product [19].

Chemical composition of Chinchin

From the chemical analysis results displayed in Table 5, it was observed that the ash content of the *Chinchin* increased significantly ($p < 0.05$) with the addition of MoLP within the 0% Control sample (0.99%) and in the 5% enriched product (1.39%). This is because MoLP high mineral content especially calcium, phosphorus, iron, and manganese [17]. The protein content of the snack showed a steady increase as the MoLP was added to each level, at 1% (6.31%) and at 5% (6.74%). This was comparable to the work done by Salama *et al.* [20], as Moringa leaves powder were added to biscuits, the crude protein increased steadily. It was also observed that the moisture decreased with the inclusion of MoLP. The moisture decreased significantly from 2.56% at Control to 1.43% at 5% MoLP. Adebayo-Oyetoro *et al.* [10] reported that the lower the moisture content of a product to be stored, the better the shelf stability of such product. The MoLP had significant effect ($p > 0.05$) on the total fat content of the Chinchin. It was noticed that the increase in MoLP from Control gave (11.60%) while at 5% MoLP gave (14.01%). This indicates that foods made from MoLP increases palatability by absorbing and retaining flavours [21]. Gbadamosi *et al.* [22] found a significant increase in the crude fat (11.67% to 17.34%) of *Chinchin* with the increased enrichment with *ugu* [23]. However, it was found that the fat content (from 14.0% to 14.2%) of cookies was significantly increased by the addition of MoLP. The total fat content depends on the amount contributed by each ingredient and on the lipids taken up during frying because *Moringa oleifera* leaves can have varying crude fat content ranging from 2 – 8% [21].

Effect of MoLP on the chemical and functional properties of *Chinchin*

The oil uptake and the moisture content of fried food products are synchronized [22]. During frying, the interior moisture of food is transformed into steam, which produces a pressure differential and big holes on the food's surface. The oil can then enter the food through the large pores due to low vapour pressure. The amount of absorbed oil increases as water from the food product evaporates more throughout the frying process [22]. In other words, lesser oil absorption in food samples is correlated with better moisture retention. Results from Table 6 show that there was an increase in the oil uptake level at 1% and 5% and the Control is significantly ($p < 0.05$) lower in comparison to dough at the other two levels. The moisture loss decreased in the dough sample with the addition of MoLP. Kwinda *et al.* [1] reported that the quality of food after the frying process is dependent on factors such as the frying technique (deep or shallow frying), the type and quality of oil, and the characteristics of the food material being fried. However, a relationship between the initial moisture and oil uptake highlighted that low moisture content would result in low oil absorption. In this study, the dough with the lowest moisture content (18.07%) resulted in the product with the highest oil uptake (7.12%). The increased oil uptake may be due to the quality of the oil used, as the oil composition has been found to have a pronounced effect on fat uptake [27]. The quality of the oil used may have deteriorated with every batch fried, and because the 5% MoLP product was last to be fried (54.79%), this may have caused the difference between it and the 0% sample which was fried (48.99%) in fresh oil. This is because three samples were used for the composition, with just MoLP being the only supplement at 1% and 5%. A change in oil was not required but after experimenting, it was observed that deterioration in the quality of the oil was affected. The ideal process was to have a different batch of oil for each sample produced. Concerning the effect of MoLP on the textural properties of raw dough and fried Chinchin, the results of the texture profile analysis show that the addition of MoLP had no significant effect ($p > 0.05$) on the dough firmness, resilience, and chewiness. In other words, the statistics imply that the factors under investigation

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have a considerable impact on the snap force, hardness, springiness, and gumminess in these sensory qualities. Note that the p-value is frequently employed to determine the statistical significance of an effect. Using the senses of sight, hearing, touch, and kinesthetics, people may identify the structural, mechanical, and surface characteristics of food through their sense of texture. Foods' structure is what gives them their texture. This result has implications on the production of *Chinchin* dough in the stages when it must be handled, cut, or manipulated because the addition of MoLP may slightly require more robust equipment (or more energy or force) to account for the significant ($p < 0.05$) difference in snap force, hardness, springiness, and gumminess. The most recurrent parameters among solid food texture attributes are hardness, springiness, cohesiveness, and friability [29]. The functional attributes in this study reveal that the snap force, hardness, springiness, and gumminess are more reliable measures than from the texture profile analysis, as it has been suggested that due to variance in test parameters, values are to be used with caution [29].

Colour determination of *Magwinya*

What could be initially observed after production of the fried *Magwinya* project was that there appeared to be a definite impact from the MoLP as it seemed to cause the 1% sample and, more so, the 5% sample to be both greener and darker; however, during the frying process they had browned enough that the difference was lessened. When CIELAB testing was used, the results (Table 7) were evident. Both a whole and a ground sample were used to observe the colour differences and showed a significant difference in lightness between all samples. There was also a significant difference between the control and 5% ground sample in terms of the a* value, the same was witnessed with the b* value. Due to technical issues, an ^E value could not be obtained for both controls, thus impacting the ability for a significant difference to be determined. The results also indicated that each sample was lighter rather than darker, with the addition of MoLP resulting in darkened samples. The MoLP also seemed to become greener as more was added, with the whole 5% sample having a greener than-red colour. However, the results for the b* value were more varied, possibly indicating too much of a difference between an individual product for its degree of yellow or blue to be witnessed. However, a higher degree of yellow than blue was still consistently observed. A high perceivable difference was also seen with the increase of MoLP, indicating a visual impact from the addition of the MoLP [30].

Colour determination of *Chinchin*

The results from (Table 8) show that the addition of MoLP to the whole and ground *Chinchin* made it significantly ($p < 0.05$) darker and greener with no significant

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change in the yellowness or blueness. The green colour and darkening of the *Chinchin* were likely from the MoLP [25]. The colour difference between 0% and 1% was 10.50% for the whole *Chinchin* and 5.04% for the ground *Chinchin*. Between the 0% and 5%, it was 14.48% for whole *Chinchin* and 17.93% for ground. In every case, the colour difference was noticeable

Total phenolic content and antioxidant activity of *Magwinya* samples

As can be seen in the results in Table 9, there is a significant ($p < 0.05$) increase in all the samples, thus indicating that the addition of the MoLP yielded a significant impact on the product, with the 5% sample having high results indicating great phenolic content as well as antioxidant activity. Natural antioxidants have drawn a lot of attention in recent years due to their ability to neutralize the effects of the pro-oxidants in fats, oils, or food products containing fat. These antioxidants are very effective and are often only needed in very little concentrations to combat numerous free radicals. The Total phenolic content (TPC) increased significantly ($p < 0.05$) from the Control to 5% (86.47% to 291.54%). This significant ($p < 0.05$) difference can be easily attributed to the various phenolic compound present in MoLP, thus explaining why with further addition, it would have a notable impact. Various reports also indicate that *Moringa oleifera* is a rich source of phenolic compounds and thus is widely used in traditional systems of medicine [20]. The antioxidant activity can similarly be explained due to Moringa oliefera leaves containing numerous antioxidants such as ascorbic acid, flavonoids, the previously mentioned phenolics and carotenoids [17]. Phenolics and flavonoids are active antioxidant components in the leaves of *Moringa oleifera*. It was obvious from the results that DPPH radical scavenging activity was higher in 5% (2468.78%) as compared to the Control (192.58%). Due to their conjugated ring structures, redox characteristics, and carboxylic groups, which are associated in the prevention of lipid peroxidation, which is present in the 5% and lower in the Control, they may be able to scavenge free radicals [17].

Effect of MoLP on phenolic content and antioxidant activity of Chinchin

The addition of MoLP significantly increased ($p < 0.05$) both the total phenolic content (1.08 – 2.17 mg GAE/g) and the antioxidant capacity (13.41 – 53.81 µmol TE/g) (Table 10), which corresponds to an increase in the results obtained by [24] who found the phenolic content of whole wheat biscuits enriched with 5% MoLP (1.01 – 2.72 mg GAE/g). Higher phenolic content in *Moringa oleifera* can be correlated with increased antioxidant activity. This was due to the high phenolic content of MoLP at 5% incorporated into the *Chinchin* despite the effects of the high processing temperatures. The phenolic active ingredients in leaves are a useful tool for disease prevention [17]. Because of this, the compounds in Moringa

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can also control the lipid peroxidation that leads to human thrombosis, atherogenesis, and cancer [17]. Phenolic content is directly proportional to antioxidant activity, which is the case in this study.

CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

Based on the outcome of this study, it may be concluded that MoLP fortification of *Magwinya* and *Chinchin* is feasible. The inclusion of the blends of MoLP to wheat flour in the production of *Magwinya* and *Chinchin* enhanced the protein, increased the ash, and lowered the moisture contents of the food snacks at 5%. The total dough and fat uptake increased at 5% inclusion of MoLP and the oil uptake increased during frying. The phenolic content and antioxidant activity had a significant difference in the chemical and colour properties, as well as the total phenolic content and antioxidant activity between the Control sample and the samples fortified with 1% MoLP and 5% MoLP.

It is recommended to use fresh batches of oil for each sample during the frying procedure. Consumer testing should be done to evaluate how consumers react to differences in colour and other qualities like taste and texture.

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Table 1: *Magwinya* Formulations

Items	0% (original)	1%	5%
Flour (%)	47.1	46.1	42.1
Water (%)	47.1	47.1	47.1
Sugar (%)	4.8	4.8	4.8
Salt (%)	0.2	0.2	0.2
Instant yeast (%)	0.7	0.7	0.7
MoLP(%)	0	1	5

Table 2: Formulation of Chinchin

	0% MoLP	1% MoLP	5% MoLP
MoLP (g)	0.00	1.10	4.92
Flour (g)	100.01	98.90	95.08
Sugar (g)	24.19	24.20	24.20
Milk (g)	24.23	24.19	24.20
Margarine (g)	18.56	18.61	18.51
Eggs (g)	15.35	15.33	15.42
Salt (g)	0.49	0.49	0.49
Baking Powder (g)	0.48	0.49	0.49
Nutmeg (g)	0.16	0.16	0.16

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Table 3: Chemical composition of MoLP (g/100g)

Sample	MoLP
Protein	27.96±0.39
Crude Fat	7.87±1.57
Carbohydrate	47.14±1.95
Ash	10.55±0.16
Moisture	6.48 ±0.11

Table 4: Chemical composition of *Magwinya* samples (g/100g)

Sample	Protein	Moisture	Ash	Total fat dough	Total fat Magwinya	Oil uptake
Control	11.36±0.29[b]	4.63±0.74[a]	0.52±0.02[a]	0.17±0.01[a]	10.17±0.47[a]	10.00±0.47[a]
1% MOLP	12.34±0.40[a]	3.64±0.73[b]	0.66±0.01[b]	0.49±0.07[b]	12.61±0.48[b]	11.12±0.55[b]
5% MOLP	13.40±0.20[c]	3.97±0.06[c]	1.09±0.01[c]	0.81±0.07[c]	15.39±0.35[c]	15.58±0.42[a]

Values are mean ± standard deviation. Different subscripts in rows represent a significant difference (p<0.05)

Table 5: Chemical composition of deep-fried *Chinchin* and total lipids and moisture content of raw *Chinchin* dough enriched with MoLP on a dry weight basis (g/100g)

Sample	Ash	Moisture	Protein	Total fat dough	Moisture dough	Total fat
Control	0.99±0.04[a]	2.56±0.07[b]	6.27±0.03[a]	16.48±2.27[a]	23.20±0.18[b]	11.60±0.68[b]
1% MOLP	1.08±0.02[b]	2.42±0.14[b]	6.31±0.06[a]	18.67±0.10[a]	20.99±0.66[ab]	11.90±0.15[a]
5% MOLP	1.39±0.04[c]	1.43±0.07[a]	6.74±0.10[b]	19.12±0.14[a]	19.47±1.53[a]	14.01±0.63[a]

Values are mean ± standard deviation. Means with different superscripts in a column differ significantly at a 5% level (p<0.05)

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Table 6: Effect of MoLP on the chemical and functional properties of Chinchin

Sample	0% MoLP	1% MoLP	5% MoLP
Dough Sample			
Oil uptake %	1.89±1.59[a]	6.77±0.05[b]	7.12±0.08[b]
Moisture loss %	20.68±0.22[a]	18.49±0.67[b]	18.07±1.48[b]
Fried Chinchin			
Snap Force (N)	48.99±4.16[b]	51.70±0.90[a]	54.79±4.95[a]
Raw Dough			
Firmness (N)	2.21±0.07[a]	2.58±0.08[a]	3.48±0.17[a]
Hardness (N)	10.96±2.86[a]	14.59±5.70[b]	19.94±8.79[c]
Springiness (%)	89.62±4.11[c]	83.47±12.32[b]	77.71±6.89[a]
Resilience (Cohesive Force)	2.49±0.54[a]	2.35±0.26[a]	2.31±0.26[a]
Gumminess (N)	34.33±9.10[c]	49.62±25.75[b]	58.89±24.99[a]
Chewiness (J)	0.52±0.14[a]	0.74±0.39[a]	0.88±0.38[a]

Values are mean ± standard deviation. Means with different superscripts in a column differ significantly at a 5% level of probability (p<0.05)

Table 7: Colour results of Magwinya samples

Sample	L* values	a* values	b* values	^E
Control Whole	59.62±0.59[a]	3.31±2.11[a]	16.72±0.88[a]	±
1% MoLP	40.84±1.32[b]	1.42±7.40[a]	25.66±6.82[a]	22.59±2.26
5% MoLP	31.77±1.18[c]	-1.75±4.34[a]	19.37±5.16[a]	28.64±0.21
Control Ground	40.62±0.62[a]	12.15±0.01[a]	17.64±1.37[a]	±
1% MoLP	31.10±1.00[b]	7.69±0.58[a]	19.32±0.23[a]	10.72±0.33
5% MoLP	20.03±2.09[c]	4.35±3.88[c]	8.75±2.46[c]	23.83±4.02

Values are mean ± standard deviation. Different subscripts in rows represent a significant difference (p<0.05). ^E (Colour difference)

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Table 8: Colour values of whole and ground *Chinchin*

Sample	L* values	a* values	b* values
Control Whole	40.68±1.38[b]	14.85±1.85[b]	37.00±2.5[a]
1% MoLP	38.74±0.25[a]	7.05±2.67[a]	35.21±4.92[a]
5% MoLP	31.30±1.03[a]	6.19±1.60[a]	35.21±4.92[a]
Control Ground	51.81±0.26[c]	9.87±0.63[b]	34.27±0.85[a]
1% MoLP	49.77±0.87[b]	7.23±2.35[ab]	35.70±4.15[a]
5% MoLP	34.92±0.56[a]	4.37±1.68[a]	32.90±2.21[a]

Values are mean ± standard deviation. Means with different superscripts in a row differ significantly at a 5% level of probability (p<0.05)

Table 9: Total phenolic content and antioxidant activity of *Magwinya* samples

Sample	FRAP umole AAE/L	TPC (mg/GEA/L)	DPPH umole TE/L
Control	258.73±12.71[a]	86.47±3.58[a]	192.58±12.67[a]
1% MOLP	430.14±105.24[b]	112.85±2.05[b]	673.15±44.46[b]
5% MOLP	1046.48±42.83[c]	291.54±12.60[c]	2468.78±194.66[c]

Values are mean ± standard deviation. Different subscripts in rows represent a significant difference (p<0.05). Ferric reducing ability of plasma (FRAP). Total phenolic content (TPC). 2,2-diphenylpicrylhydrazyl (DPPH)

Table 10: Total phenolic content and antioxidant capacity of *Chinchin* fortified with MoLP

Sample	Total Phenolic Content (mg GAE/g)	Total antioxidant capacity (μmol TE/g)
Control	1.08±0.05[a]	13.41±0.09[a]
1% MOLP	1.26±0.06[b]	17.90±2.33[b]
5% MOLP	2.17±0.07[c]	53.81±2.94[c]

Values are mean ± standard deviation. Means with different superscripts in a column differ significantly at a 5% level of probability (p<0.05)

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