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▶ **To cite this version:**

Pius Emesu, Cynthia Oratile Makgale, Gulelat Desse Haki. Sensory and Nutritional Quality of Cookies Supplemented with Wheat Bran and Lerotse (Citrullus lanatus var. citroides) Pulp from Botswana. Asian Food Science Journal, 2025, 24 (4), pp.1-8. ⟨10.9734/afsj/2025/v24i4778⟩. ⟨hal-04981512⟩

HAL Id: hal-04981512

https://hal.science/hal-04981512v1

Submitted on 7 Mar 2025

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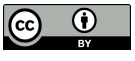

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Asian Food Science Journal

Volume 24, Issue 4, Page 1-8, 2025; Article no.AFSJ.131876
ISSN: 2581-7752

Sensory and Nutritional Quality of Cookies Supplemented with Wheat Bran and Lerotse (*Citrullus lanatus var. citroides*) Pulp from Botswana

Pius Emesu [a*], Cynthia Oratile Makgale [b] and Gulelat Desse Haki [b]

[a] Department of Agricultural and Biosystems Engineering, Botswana University of Agriculture and Natural Resources, Lot1, A1 Road, Content Farm, Sebele, Private Bag 0027, Gaborone, Botswana.
[b] Department of Food Science and Technology, Botswana University of Agriculture and Natural Resources, Lot1, A1 Road, Content Farm, Sebele, Private Bag 0027, Gaborone, Botswana.

Authors' contributions

This work was carried out in collaboration among all authors. Authors PE, COM and GDH collaborated in the design and conduct of this study. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/afsj/2025/v24i4778

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/131876

Short Research Article

Received: 01/01/2025
Accepted: 03/03/2025
Published: 06/03/2025

ABSTRACT

Lerotse or Kalahari melons which are usually planted as ground cover in crop fields in Botswana are rich in potassium, carotenoids and citrulline. However, they are undervalued and often go to waste. As a strategy of value addition and post-harvest waste-reduction, cookies were formulated using varying blends of lerotse pulp and wheat bran. The effects of this supplementation on cookie

**Corresponding author: Email: pemesu@buan.ac.bw, pemesu@yahoo.com;*

Cite as: *Emesu, Pius, Cynthia Oratile Makgale, and Gulelat Desse Haki. 2025. "Sensory and Nutritional Quality of Cookies Supplemented With Wheat Bran and Lerotse (Citrullus Lanatus Var. Citroides) Pulp from Botswana". Asian Food Science Journal 24 (4):1-8. https://doi.org/10.9734/afsj/2025/v24i4778.*

acceptability and nutritional quality were determined through sensory evaluation and Nutri-Score calculation, respectively. Bran cookies without lerotse supplementation (the control sample) received low overall liking of 5.9. However, increasing the lerotse-to-bran ratio from 0.25 to 4.0 resulted in an increase in overall liking from 5.8 to 7.65, with a significant difference (P =.05). Significant differences were was also observed between the samples in terms of aroma, while other sensory properties did not differ significantly amongst all samples at P =.05. The Nutri-Score classification changed from A (dark green) in the lerotse-free cookies to B (green) in samples with lerotse-to-bran ratio of 0.25 and to C (yellow) in samples with lerotse-to-bran ratio between 0.67 and 4.0. For lerotse-containing cookies, a Nutri-Score rating of B represents good nutritional quality while a rating of C indicates moderate nutritional quality. Therefore, incorporating lerotse and wheat bran at a ratio of 0.25 produced a moderately liked product of good nutritional quality. Further optimization of the formulation could be achieved through chemical and physical characterization, potentially leading to commercially viable products that would increase lerotse utilization.

Keywords: Cookies; lerotse/Kalahari melon; wheat bran; sensory evaluation; nutritional quality; Nutri-Score.

1. INTRODUCTION

Lerotse (*Citrullus lanatus var. citroides*), also known as citron/Kalahari/cooking/fodder melon, is a drought-tolerant under-utilized wild melon that thrives under minimal agronomic management in the arid and semi-arid regions of Botswana where it is commonly planted as a companion or cover crop. Alternatively called lekatane in the Tswana language, it is related to but less sweet than the common watermelon with pulp colour ranging from white-green, to yellow or orange. Owing to its low sweetness, it is traditionally added to and cooked with sorghum or maize meal to make porridge known as *bogobe jwa lerotse*. Another traditional cooked product is known as *kgodu*, in which lerotse rind is cooked and either served straight or mixed with milk (Bultosa et al., 2020). Additionally, it is commonly sundried into a traditional product locally known as *lengangale* (dried melon slices) to extend its shelf-life. Nutritionally, lerotse melon flesh or pulp is a good source of potassium, carotenoids and citrulline - a non-essential amino acid that can reduce muscle soreness and improve heart rate recovery after exercise – while other components of the plant such as seed, peel, leaves and roots contain significant amounts of various macro- and micro-nutrients and phytochemicals important for human health (Nkoana et al., 2022). Nutritionally useful as lerotse may be, its current traditional applications are, however, insufficient to mitigate its wastage as it usually ends up being cast to domestic animals as alternative feed, hence product development efforts are needed to deliver commercially viable value-added food and non-food products from it.

According to FAO and WHO (2019), sustainable healthy diets are dietary patterns that promote all dimensions of an individual's health and wellbeing, which is recommended to contain a great variety of wholesome, unprocessed or minimally processed foods including wholegrains, legumes, nuts, an abundance of fruits and vegetables, and can include moderate to low amounts of animal foods. The Global Nutrition Report (2023) further reveals that for adults aged over 20 years in Botswana, their intake of fish and dairy foods lies within recommended limits, while intakes of nuts and red meats exceed recommended intake levels, and intake of fruits, vegetables, legumes, and whole grains, fall short of the recommended levels. Furthermore, FAOSTAT data (FAO, 2023) shows that over 60% of the population in Botswana is unable to afford a healthy diet, signifying the need to increase the supply of nutritious and affordable food, of which product development harnessing underutilized species like lerotse as reported herein could alleviate the situation.

Consumers who wish to adopt sustainable healthy diets need access to easy-to-understand nutritional label information, which traditionally is indicated on the back-of-package Nutrition Facts Panels (Soederberg Miller et al., 2015). However, many national agencies are currently investigating and promoting the use of front-of-package labelling systems to provide more details to help consumers align their food choices to recommended dietary guidelines. The Nutri-Score is a nutrient-specific, five-colour nutrition label ranging from dark green corresponding to Nutri-Score A for better nutritional quality food, to

dark orange, corresponding to Nutri-Score grade E for lower nutritional quality food (Tachie et al., 2023). The score is calculated using an algorithm that awards positive scores of 0-10 to nutrients whose intake should be minimized or limited (energy, saturated fatty acids, sugars and sodium), and negative scores of 0-5 for nutrients that should be encouraged (fibre, proteins, fruits, vegetables, pulses, nuts, and rapeseed, walnut and olive oils).

By summing the positive and negative points, the global score which can range between -15 for the healthiest foods and +40 for the least healthy foods, is obtained (Zabetakis et al., 2022). Based on a nutrient profiling system published in the UK, the Nutri-Score algorithm was developed in France and is being now recommended for use in other European countries including Belgium, Switzerland, Germany, Spain, the Netherlands and Luxembourg. Internationally, it has been favourably evaluated in South Africa (Hutton et al., 2020), Morocco (Aguenaou et al., 2021), Korea (Ahn and Lee, 2022), and adapted in Singapore (Shin et al., 2023), among others.

Cookies are versatile bakery snack products that are popular across many cultures and are a suitable vehicle for incorporation of ingredients such as fruit and vegetables for enhanced functionality (de Toledo et al., 2017; Ertaş and Aslan, 2020). Cookie formulations usually include flour, liquid, eggs, fat, leaven and sugar (Vaclavik and Christian, 2014), with the addition of other grains, fruits, vegetables and nuts to modify appearance, texture, flavour and to boost nutritional and health benefits. Wheat bran is a by-product of the dry milling of the common wheat (*Triticum aestivum* L.) into flour, and it can be incorporated into baked products, soups and fruit salads primarily for dietary fibre enrichment. Several authors have reported on technological, nutritional and sensory properties of cookies enriched with wheat bran and fruit (El-Sharnouby et al., 2012; Gujral et al., 2003; Lauková et al., 2016, 2019). Therefore, the current study investigated the effects of lerotse-to-bran ratio on the sensory and nutritional quality of cookies using a sensory evaluation panel and the Nutri-Score algorithm (Santé Publique France, 2024), respectively.

2. MATERIALS AND METHODS

2.1 Raw Materials Acquisition and Processing of Lerotse

Wheat bran meal and other cookie ingredients were purchased from a local supermarket while lerotse was obtained from a local farmer from Gaborone.

Lerotse fruits were washed using tap water to remove dirt from the rind, cut into thin slices and manually deseeded. The slices were then chopped up into smaller pieces and blended using a food blender for 2 minutes to produce lerotse pulp. The pulp was then stored in a refrigerator before being used for baking.

2.2 Cookies Formulation

Cookies were prepared according to a recipe adapted from Molewa (1994), using the following ingredients: 75 g wheat flour, 75 g corn flour, 50 g sugar (brown), 125 ml sunflower oil (118 g), 2 medium-sized eggs (100 g), 0.5 g salt, 2.5 g baking powder, and 0.5 g of vanilla essence. Wheat bran using the levels depicted in Table 1 was mixed with sugar and sunflower oil and then left overnight at room temperature. As per the relevant treatment shown in Table 1, lerotse was mixed with eggs, salt, wheat flour, corn flour, baking powder and vanilla essence and then blended with the bran mixture until uniformity was achieved. The batter was rolled and cut with a circular cookie cutter, placed on baking trays with 25 mm spacing and then baked in a Defy 835 oven (Defy Appliances, Durban, South Africa) at 160ºC for 15 minutes. After baking, the cookies were cooled and taken for sensory evaluation.

Table 1. Wheat bran and lerotse mixing ratios

Treatment	Wheat bran content (g)	Lerotse content (g)	Lerotse:Bran Ratio
1	100	0	0.0
2	80	20	0.25
3	60	40	0.67
4	50	50	1.0
5	40	60	1.5
6	20	80	4.0

2.3 Sensory Evaluation

Affective sensory evaluation of cookie samples was done by 20 selected assessors (Sipos et al., 2021) with working knowledge on sensory valuation, using a 9-point hedonic scale for the following attributes: colour, aroma, sweetness, texture and overall liking. The scale ranged from 1 representing extreme dislike, through 5 being a centre neutral category representing neither like nor dislike, to 9 representing extreme liking (Lawless and Heymann, 2010). The cookies were three-digit encoded and presented to panelists in random order. Panelists were advised to avoid using strongly odorous materials such as soaps, lotions and perfumes prior to participating in the exercise and to refrain from eating, drinking or smoking at least 30 minutes prior to the sensory test. A tumbler of drinking water was provided for rinsing the mouth between testing different samples.

2.4 Nutri-Score Computation

Nutrient contents of ingredients used in the cookie formulations were obtained from the following databases: Food Data Central (https://fdc.nal.usda.gov) curated and maintained by the U.S. Department of Agriculture (USDA), Agricultural Research Service (U.S. Department of Agriculture, 2024), Vegan Nutrition Tracker (https://vegnt.com), and Lesotho food composition tables (Lephole et al., 2006) with lerotse composition being adapted from de Azeredo et al. (2022). The energy content in kJ/100g, sugar and saturated fat contents, each in g/100g, salt content in mg/100g, fruit, vegetable and legumes content in percentage, and fibre and protein contents, each in g/100g, for each treatment were computed, which constituted the inputs required for computation of the Nutri-Score, as shown in Table 3. The updated Nutri-Score algorithm as published by Santé Publique France (2024) was obtained from https://www.santepubliquefrance.fr/ as a preconfigured spreadsheet file.

2.5 Data Processing

Raw sensory evaluation data was captured and pre-processed in Microsoft Excel Spreadsheet (Microsoft 365, Release 16.0) while the R Statistical Environment, version 4.4.0 (R Core Team, 2024) was used to establish statistical inferences at $\alpha = 0.05$ using the two-tailed analysis of variance (ANOVA) and separation of means was done using the Tukey HSD test.

3. RESULTS AND DISCUSSION

3.1 Sensory Properties

A summary of mean sensory scores as influenced by the content of lerotse in the formulation is presented in Table 2, wherein it may be observed that increasing lerotse pulp relative to wheat bran content in the formulation positively influenced all cookie sensory parameters, with the formulation having the highest lerotse-to-bran ratio of 4.0 receiving the highest rating across all parameters.

Cookie colour ratings ranged from 5.8 to 7.1, while sweetness and texture ratings ranged from 6.7 to 7.35 and 5.5 to 7.3, respectively, reflecting slight to moderate liking, with the formulation not containing lerotse pulp receiving the lowest ratings. For these parameters, however, no statistically significant difference was found as the lerotse-to-bran ratio increased, at P = .05 level of significance.

Furthermore, results showed significant differences in both overall liking and aroma between the samples containing lerotse-to-bran ratios of 4.0 and 0.25, at P = .05 level of significance. It should be noted that the computed percentage of lerotse pulp relative to the total ingredients mass in the highest rated sample was 15.4%, but whether more could be incorporated would need further investigation including instrumental texture evaluation for confirmation. In a similar study employing melon peels, Ertaş and Aslan (2020) found that using 2.5% melon peel flour coupled with 1.25% melon seed flour gave the best general acceptability for cookies. In contrast, Zarroug et al. (2021) found that increasing the amount of Tunisian *Zizyphus lotus* L. fruit in a cookie formulation reduced product acceptability as the fruit introduced unfavourable taste.

3.2 Nutri-Score Profiling of Lerotse-Bran Cookies

Nutri-Score profiles of the lerotse-bran cookies are shown in Table 3, wherein are included the scores for the major ingredients used in the formulations, and bran crackers whose composition is derived from the FDC database (U.S. Department of Agriculture, 2024) for comparative purposes. It is visually clear that as lerotse-to-bran ratio increased, the Nutri-Score rating declined from green in the lerotse-free sample to yellow in the sample which had

Table 2. Effects of lerotse content on cookie sensory properties

Lerotse:Bran Ratio	Lerotse content* (%)	Colour	Aroma	Sweetness	Texture	Overall Liking
0.0	0	5.8	6.1	6.7	5.5	5.9
0.25	4	5.85	5.25[a]	6.2	5.85	5.8[a]
0.67	8	7	6.25	6.65	6.1	6.7
1.0	10	6.55	5.9	6.05	6.15	6.05
1.5	12	6.6	6.9	7.1	6.85	7.2
4.0	15	7.1	7.85[a]	7.35	7.3	7.65[a]

For each parameter, mean values with the same superscript are significantly different at P = .05
**Lerotse content was computed as percentage of total mass of ingredients in the formulation*

Table 3. Nutri-Score profile of lerotse-bran cookies and selected ingredients

Food Product	Energy (kJ/100g)	Sugar (g/100g)	Saturates (g/100g)	Salt (g/100g)	Fruits, vegetables and legumes (%)	Fibre (g/100 g)	Protein (g/100 g)	Score	Nutri-Score	Colour
Sugar, brown	1596	100.0	0.0	0.0	0.0	0.0	0.12	19	E	dark orange
Wheat bran	1133	0.4	0.6	0.1	0	42.8	15.6	-8	A	dark green
Citron Melon	1587	3.4	0.0	0.0	100	2.6	1.2	-1	A	dark green
Sunflower oil	3780	0.0	9.0	0.0	0.0	0.0	0	18	D	orange
LB0.0 cookies	1786	10.2	2.8	0.2	0.0	9.5	8.1	2	B	green
LB0.25 cookies	1803	10.3	2.8	0.2	3.8	8.0	7.6	2	B	green
LB0.67 cookies	1820	10.4	2.8	0.2	7.7	6.4	7.0	4	C	yellow
LB1.0 cookies	1829	10.5	2.8	0.2	9.6	5.7	6.7	5	C	yellow
LB1.5 cookies	1838	10.5	2.8	0.2	11.5	4.9	6.5	6	C	yellow
LB4.0 cookies	1855	10.6	2.7	0.2	15.4	3.4	5.9	7	C	yellow
Bran crackers (FDC)	1802	3.6	0.0	0.9	0	7.1	10.7	2	B	green

Product codes LB0.0, LB0.25, LB0.67, LB1.0, LB1.5 and LB4.0 represent cookie samples with lerotse-to-bran ratios of 0.0, 0.25, 0.67, 1.0, 1.5, and 4.0, respectively

lerotse-to-bran ratio of 4.0. Numerically, the scores gradually increased from 2 to 7, corresponding to Nutri-Score B and Nutri-Score C classifications, respectively. The green (Nutri-Score B) rating obtained for the lerotse-free cookie sample is corroborated by that of bran crackers whose composition was taken from the FDC database (Table 3), indicating their good nutritional quality. Ingredients with good nutritional ratings included wheat bran and citron melons, while sugar and cooking oil had low ratings as per the dietary guidelines which underpin both the Nutri-Score and FAO sustainable healthy diets (FAO and WHO, 2019; Zabetakis et al., 2022).

Bran content had a stronger influence on the Nutri-Score value than fruit content of the formulation since the algorithm begins rewarding favourable points at level of 0.7 g fibre/100 g of food, whereas higher levels are required for fruits and vegetables >40 g /100 g of food to begin accumulating favorable points (Zabetakis et al., 2022). With respect to fruit content, lerotse content in all the samples ranged between 0 and 15.4%, falling short of the minimum amount to obtain favourable points, thus lerotse content did not strongly influence the Nutri-Score rating of all cookies. The results suggest that lerotse bran cookies having a lerotse-to-bran ratio of 0.25 or less, would produce a healthy snack item, while those having higher fruit-to-bran content from 0.67 to up to 4.0 would produce moderately healthy snacks.

Tachie et al. (2023) have combined macro- and micro-nutrient compositions of plant-based-foods to predict their Nutri-Scores as a measure of nutritional quality using machine learning. In addition, Deschasaux-Tanguy et al. (2024) conducted a large prospective study among European adults and reported higher risk of cardiovascular diseases in individuals consuming a diet with lower nutritional value – corresponding to a lower Nutri-Score value – which highlighted the relevance of the updated Nutri-Score algorithm to characterize foods with a healthier nutrient profile.

4. CONCLUSIONS AND RECOMMENDATIONS

Effects of increasing fruit pulp-to-bran ratio on the quality of cookies formulated using lerotse, i.e. citron melon (*Citrullus lanatus var. citroides*) and wheat bran were studied using affective sensory evaluation and computation of Nutri-Score as a nutritional quality measure. Increasing the fruit content led to increased positive ratings for all sensory parameters, but significant differences were only recorded with respect to aroma and overall liking between cookies having lerotse-to-bran ratios of 0.25 and 4.0 at P = .05 level of significance. The Nutri-Score classification decreased with increasing fruit-to-bran ratio, transiting from A in the lerotse-free sample to B in the lowest lerotse-to-bran ratio (0.25) and to C in the samples with higher lerotse-to-bran ratios (0.67-4.0). It may be concluded that use of lerotse and bran led to production of sensorially acceptable cookies with slight-to-moderate overall liking, with good to moderately good nutritional properties, and would be recommended for further product development and optimisation. It is further recommended that instrumental texture and chemical evaluation are needed to characterize products using the resultant optimized formulations, which would stimulate commercialization and increase the utilization of lerotse.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

ACKNOWLEDGEMENTS

Material and financial support from the Botswana University of Agriculture and Natural Resources in the conduct of this work is duly recognized and appreciated.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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