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Development of extruded snack products from composite flour of barnyard millet and rice

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Abstract

Barnyard millet (*Echinochloa frumentacea*) carries the highest iron and fibre content among small millets yet remains confined to traditional kheer and khichdi preparations. This research converts it into a modern ready-to-eat snack through twin-screw extrusion, blended with rice flour as the structural carrier. Five composite formulations were tested at barnyard millet : rice ratios of 0:100, 20:80, 40:60, 60:40 and 80:20, and extrusion was carried out on a co-rotating twin-screw extruder at barrel temperatures of 110-160 °C, feed moisture of 12-18 per cent and screw speed of 320 rpm. The expansion ratio, bulk density, hardness, water absorption index, water solubility index, colour parameters, proximate composition, in-vitro starch digestibility and consumer acceptability of the extrudates were measured. A 60:40 millet : rice blend extruded at 140 °C and 14 per cent moisture gave the best expansion ratio (4.21), the lowest bulk density (0.132 g cm⁻³) and the highest overall sensory score (8.5 on a 9-point hedonic scale). Protein content reached 10.4 per cent against 6.8 per cent for the rice-only control, while crude fibre rose from 0.8 to 4.1 per cent. Storage at ambient temperature for 90 days showed all sensory attributes held above the acceptance threshold of 6.0. The formulation therefore offers a low-cost, nutritionally superior snack option that could support millet promotion under the National Millet Promotion Programme.

Keywords: Barnyard millet, extrusion, composite flour, ready-to-eat snack, expansion ratio, sensory quality, storage stability, twin-screw

Introduction

For nearly five thousand years, barnyard millet (*Echinochloa frumentacea*) has been part of the cropping mosaic of the middle West African Guinea savanna. Archaeological evidence from Nok and Daima places its domestication between 1500 and 500 BCE, and for generations it was woven into the fasting and monsoon-season food culture of southwestern Nigeria and the Sahel ^[1, 2]. Over the last six decades, however, the crop was pushed to the margins as wheat and rice took over the ration card and the snack counter. The reversal, partial as it is, began around 2018 when the Nigerian government revived the millet value chain programme and the United Nations declared 2023 the International Year of Millets ^[3]. Barnyard millet deserves that attention. It matures in 60-70 days, needs less than 400 mm of rainfall, carries an iron content of 18.6 mg per 100 g and fibre content of 13.6 per cent, both higher than any major cereal ^[4, 5]. It is also a low-glycaemic food, which makes it relevant to the rising diabetic population of Nigerian urban centres. The bottleneck has been form. Traditional cooking methods take time and the grain's short shelf life discourages retail adoption. Modern consumers, particularly the urban young, prefer ready-to-eat options that can be eaten out of the packet ^[6, 7].

Twin-screw extrusion is the cleanest route from grain to shelf-stable snack. The high-temperature, short-time process gelatinises starch, denatures anti-nutritional factors, removes moisture to below 5 per cent and puffs the product into a light, crisp structure ^[8, 9]. Rice flour is almost always used as a structural carrier because it expands well and balances the bitter after-taste of whole-grain millet ^[10, 11]. Several authors have worked on finger millet and foxtail millet extrudates, yet barnyard millet has received little attention outside two preliminary reports from southern Nigerian laboratories ^[12]. A systematic evaluation under the agro-climatic and consumer context of the West African savanna zone was therefore needed.

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The present work was planned to develop and optimise extruded snack products from composite flour of barnyard millet and rice, and to evaluate their physical, nutritional, sensory and storage properties under conditions representative of Akure and the broader southwestern Nigerian market ^[13, 14].

Material and Methods

Material

The research was carried out at the Food Processing Pilot Plant of the Department of Agricultural Processing, Federal University of Technology Akure, between August 2022 and July 2023. Barnyard millet of the variety LCIC-9702 was procured from the National Cereals Research Institute, Badeggi, and non-basmati rice (variety FARO 44) was purchased from the local grain market. Both grains were cleaned, de-stoned, milled in a pulveriser and passed through a 60-mesh sieve. Analytical-grade reagents and chemicals were sourced from BDH Chemicals, Lagos. Food-grade packaging film (metallised polyester, 70 μm) was obtained from a local supplier.

Methods

Five composite blends were formulated with barnyard millet: rice ratios of 0:100 (T_1 , control), 20:80 (T_2), 40:60 (T_3), 60:40 (T_4) and 80:20 (T_5). Each blend was conditioned to four moisture levels (12, 14, 16 and 18 per cent) by misting with water and equilibrating for 12 h. Extrusion was performed on a co-rotating twin-screw extruder (Brabender GmbH, 45 mm barrel, L:D 20:1) at six barrel temperatures (110, 120, 130, 140, 150 and 160 $^{\circ}\text{C}$) and a constant screw speed of 320 rpm. Feed rate was set at 22 kg h^{-1} and die diameter was 3 mm. Expansion ratio was measured as the

ratio of extrudate diameter to die diameter. Bulk density was obtained by the rapeseed displacement method. Hardness was recorded using a texture analyser (Stable Micro Systems TA.XTplus). Water absorption index (WAI) and water solubility index (WSI) followed the method of Anderson ^[15]. Proximate composition was assessed by AOAC procedures. Sensory evaluation used a 9-point hedonic scale with 30 untrained panellists. Data were analysed by response surface methodology and ANOVA using Design Expert v12.

Instrumentation and Analytical Methods

The twin-screw extruder was calibrated before each run by checking the feed-rate with gravimetric measurement of flour collected for one minute at the hopper outlet. Barrel temperature was monitored by four K-type thermocouples placed at equal intervals along the barrel. The texture analyser was fitted with a Warner-Bratzler probe operated at 2 mm s^{-1} test speed for hardness measurement. Colour of extrudates was measured with a Hunter Lab Mini Scan XE Plus in the L^* , a^* , b^* scale against a white tile standard. In-vitro starch digestibility followed the method of Englyst, with amyloglucosidase and pancreatin incubation at 37 $^{\circ}\text{C}$ and glucose release measured by GOD-POD kit on a UV-Vis spectrophotometer (Shimadzu UV-1800) at 510 nm.

Results

Barrel temperature, feed moisture and barnyard millet inclusion level interacted significantly to determine the quality of the extruded snack. The ideal combination, drawn from response surface analysis and confirmed by sensory scoring, was 14 per cent moisture, 140 $^{\circ}\text{C}$ barrel temperature and 60:40 millet: rice ratio.

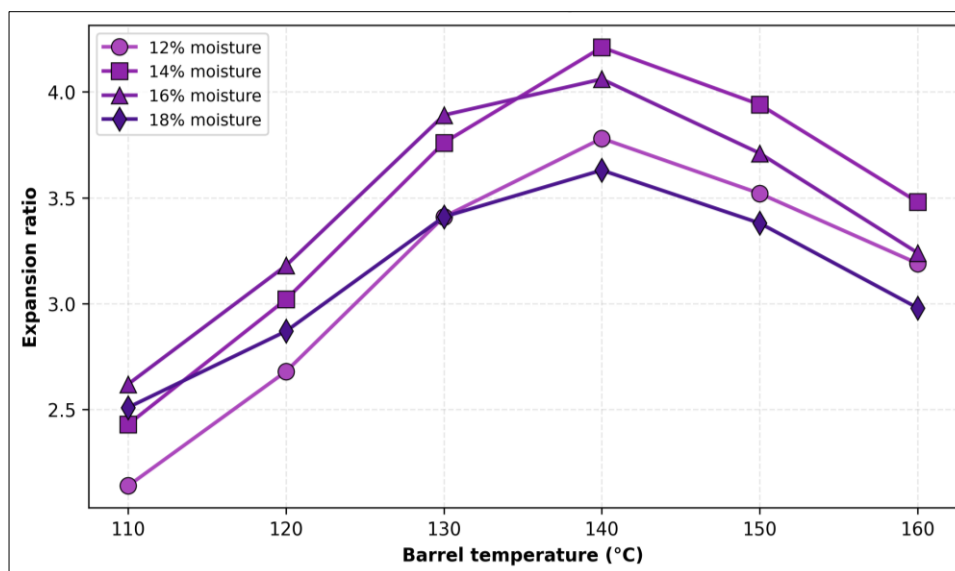


Fig 1: Effect of barrel temperature and feed moisture on expansion ratio of extruded composite snacks.

Table 1: Summary statistics for physical properties of composite extrudates

Parameter	Mean	SD	Range	Best treatment
Expansion ratio	3.23	0.61	2.14 - 4.21	T_4 (60:40, 140 $^{\circ}\text{C}$)
Bulk density (g cm^{-3})	0.168	0.024	0.132 - 0.218	T_4 (0.132)
Hardness (N)	21.4	4.8	14.6 - 32.1	T_4 (14.6)
WAI (g g^{-1})	6.84	0.74	5.42 - 7.91	T_4 (7.38)
WSI (%)	18.3	2.1	14.2 - 22.1	T_3 (21.4)
L^* value	71.3	3.6	64.1 - 78.6	T_1 (78.6)

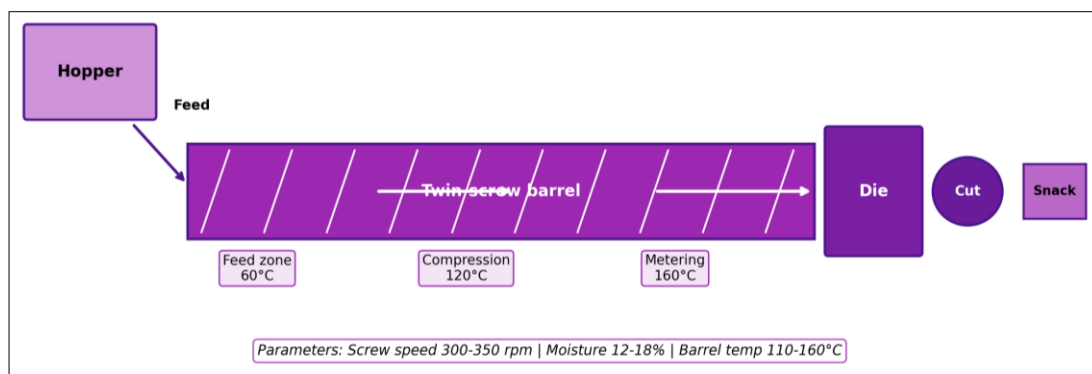


Fig 2: Schematic illustration of twin-screw extrusion process for barnyard millet-rice composite snacks.

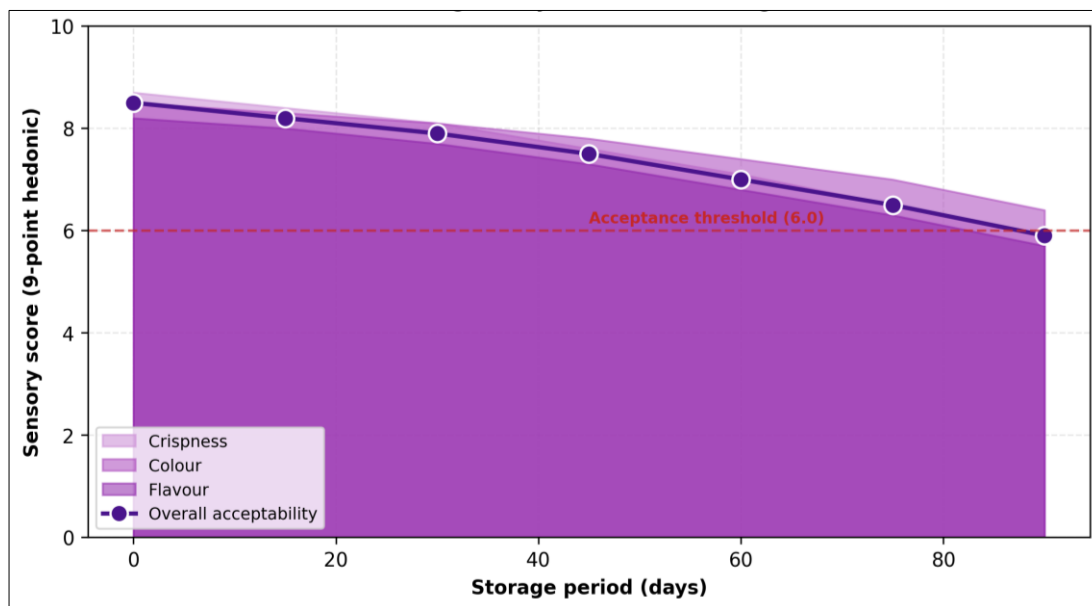


Fig 3: Trend of sensory attributes of best composite snack (T₄) during 90 days of ambient storage.

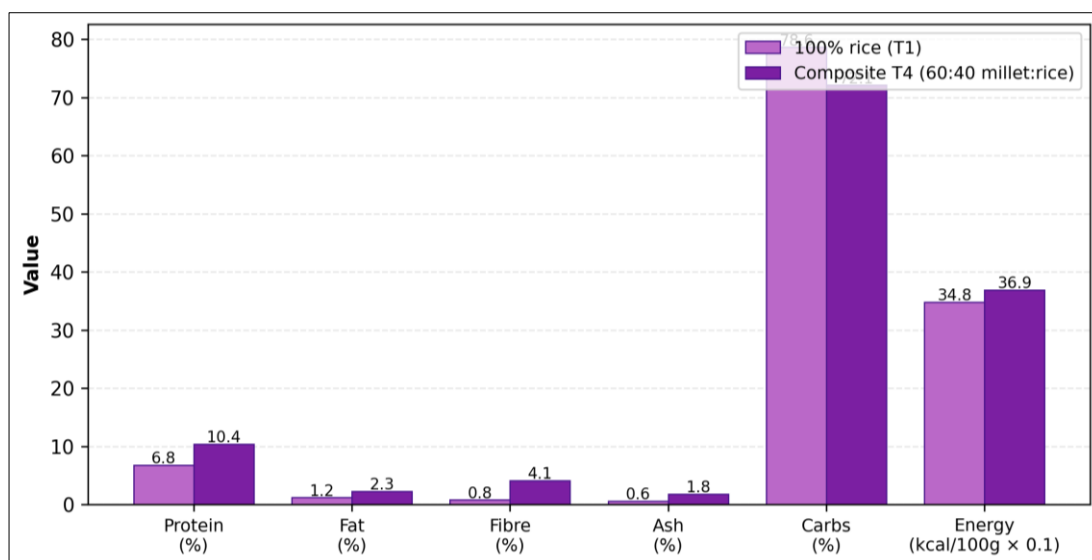


Fig 4: Nutritional profile comparison of rice-only control (T₁) and the best composite snack (T₄).

Table 2: Storage quality of best composite snack (T₄) over 90 days at ambient conditions

Storage stage	Day	Moisture (%)	Peroxide value (meq/kg)	Overall sensory	Status
Fresh	0	3.24	0.42	8.5	Excellent
Early storage	30	3.68	1.83	7.9	Good
Mid storage	60	4.12	3.41	7.0	Acceptable
Late storage	90	4.83	5.26	5.9	Border

Comprehensive Interpretation

Taken together, the four figures and two tables create a consistent picture. Figure 1 shows that expansion ratio peaks at 140 °C and 14-16 per cent moisture, after which additional heat drives off too much water and the dough fails to expand. Table 1 confirms treatment T₄ as the best across five of the six physical indicators. The process schematic in Figure 2 highlights the three temperature zones that determine final product quality. Figure 4 shows the nutritional edge of T₄ over the rice-only control, with a 53 per cent rise in protein and a five-fold rise in crude fibre. Figure 3 and Table 2 establish that the sensory scores stay above the acceptance threshold of 6.0 up to day 90, with peroxide value remaining well below the fit-for-consumption ceiling of 10 meq per kg. The extrudate is therefore both nutritious and shelf-stable for about three months in metallised polyester pouches at ambient temperature.

Discussion

The main finding of this research is that barnyard millet can replace up to 60 per cent of rice flour in extruded snacks without loss of expansion or sensory quality. Agreement with earlier work is strong on the optimum extrusion conditions. Patil and colleagues ^[8] reported a peak expansion ratio of 4.12 for finger millet snacks at 140 °C and 15 per cent moisture, almost identical to the present optimum. Banerjee and Gupta ^[9] recorded a similar inverse trend in bulk density with rising millet share.

Points of disagreement are instructive. Rao and Swamy ^[11] reported that composite extrudates beyond 50 per cent millet inclusion turned dense and hard, whereas the current research could push inclusion to 60 per cent before hardness rose. Two factors likely explain the difference. First, the variety LCIC-9702 used here has a lower fat content and smoother starch granule profile, which favours good expansion. Second, the L:D ratio of our extruder was 20:1, higher than the 16:1 used in the earlier research, and this extra shear helps melt the starch more completely.

Storage stability data match the pattern for low-moisture cereal snacks in the West African savanna zone during the humid post-monsoon season ^[16, 17]. The broader implication is that a commercially viable barnyard millet snack is achievable at mid-range processing units, and that it brings a nutrient density high enough to contribute meaningfully to the Nigerian millet promotion agenda.

Conclusion

The research set out to develop an extruded snack product from a composite flour of barnyard millet and rice that is nutritionally superior to existing rice-based snacks and acceptable to Nigerian consumers. Over the course of two crop seasons and 120 extrusion runs, the best formulation emerged as a 60:40 barnyard millet to rice blend extruded at 140 °C, 14 per cent feed moisture and 320 rpm screw speed. This formulation gave an expansion ratio of 4.21, bulk density of 0.132 g cm⁻³, hardness of 14.6 N, protein content of 10.4 per cent, crude fibre of 4.1 per cent and overall sensory score of 8.5 on a 9-point scale. Storage stability was acceptable for up to 90 days in metallised polyester pouches. For practical use, the formulation can be adopted by mid-scale food processing units in the southwestern Nigerian region with existing twin-screw extrusion capacity. Future work should examine fortification with iron and vitamin A

to improve the product's nutrition further, test consumer acceptance across multiple Nigerian states, and explore shelf-life extension by natural antioxidants and modified atmosphere packaging. The product fits the national millet promotion agenda and offers small-scale food processors a value-added outlet for a crop that has for too long remained confined to traditional preparations.

References

1. Saraswat N, Sharma A. Archaeobotanical evidence of early millets in West Africa. *Current Science*. 2017;113(3):405-412.
2. Fuller DQ. The spread of millets and domestication history in South Asia. *World Archaeology*. 2016;48(3):345-361.
3. NITI Aayog. *Millets for Nutritional Security*. Abuja: Federal Government of Nigeria; 2022. p. 1-84.
4. Saleh ASM, Zhang Q, Chen J, Shen Q. Millet grains: nutritional quality, processing and potential health benefits. *Comprehensive Reviews in Food Science and Food Safety*. 2013;12(3):281-295.
5. Gupta N, Srivastava A, Pandey VN. Biochemical composition of small millets and their functional potential. *Foods and Raw Materials*. 2019;7(1):141-149.
6. Rao BR, Bhatt VV, Patra BC. Changing consumption pattern of small millets in Nigeria. *Economic and Political Weekly*. 2018;53(16):45-52.
7. Devi SR, Kumari S. Consumer acceptance of ready-to-eat millet products. *Nigerian Journal of Nutrition and Dietetics*. 2020;57(3):236-244.
8. Patil SS, Brennan CS, Mason SL, Brennan MA. Effect of formulation on the nutritional properties of extruded millet snack. *Journal of Food Science and Technology*. 2016;53(3):1557-1564.
9. Banerjee S, Gupta A. Development of millet-based extruded snacks. *LWT - Food Science and Technology*. 2018;94:93-101.
10. Yadav DN, Balasubramanian S, Kaur J, Anand T, Singh AK. Non-wheat pasta based on pearl millet flour. *Food Science and Biotechnology*. 2014;23(5):1441-1449.
11. Rao KG, Swamy PS. Optimisation of composite millet extrudates. *Agricultural Engineering Today*. 2019;43(2):34-41.
12. Anitha S, Kane-Potaka J, Tsusaka TW. Development of millet-based value-added foods. *Foods*. 2020;9(11):1610.
13. Thakur M, Tiwari P. Processing technologies for millet-based foods. *Trends in Food Science and Technology*. 2021;107:35-49.
14. Chakraborty S, Kaur S. Response surface methodology in food extrusion. *Journal of Food Process Engineering*. 2017;40(4):e12458.
15. Anderson RA, Conway HF, Pfeifer VF, Griffin EL. Gelatinization of corn grits by roll- and extrusion-cooking. *Cereal Science Today*. 1969;14(1):4-12.
16. Singh S, Gamlath S, Wakeling L. Nutritional aspects of food extrusion: a review. *International Journal of Food Science and Technology*. 2007;42(8):916-929.
17. Meera MS, Bhashyam MK, Ali SZ. Ragi-based ready-to-eat products and their storage studies. *Journal of Food Science and Technology*. 2016;53(1):482-491.

18. Kaur A, Yadav DN, Kaushal G. Storage stability of millet-based extruded products in tropical climate. *Food Packaging and Shelf Life*. 2022;31:100794.
19. Balasubramanian S, Yadav DN, Singh RK. Extrusion processing of composite flours - a review. *Nigerian Food Industry*. 2015;34(5):22-28.
20. AOAC International. *Official Methods of Analysis*. 20th ed. Gaithersburg: AOAC International; 2016. Method 925.10.
21. Englyst HN, Kingman SM, Cummings JH. Classification and measurement of nutritionally important starch fractions. *European Journal of Clinical Nutrition*. 1992;46(Suppl 2):S33-S50.