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Jepchumba Lagat
Department of Harvest Engineering, Central Kenya College of Agriculture, Nyeri, Kenya

Wairimu Ogola
Department of Harvest Engineering, Central Kenya College of Agriculture, Nyeri, Kenya

Juma Kosgei
Department of Harvest Engineering, Central Kenya College of Agriculture, Nyeri, Kenya

Kalo Ngetich
Department of Harvest Engineering, Central Kenya College of Agriculture, Nyeri, Kenya

Corresponding Author:
Jepchumba Lagat
Department of Harvest Engineering, Central Kenya College of Agriculture, Nyeri, Kenya

Development of ready-to-eat snacks from composite flour of millets and legumes

Jepchumba Lagat, Wairimu Ogola, Juma Kosgei and Kalo Ngetich

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Abstract
Food scientists have long argued that underused crops like finger millet and sorghum could anchor a new generation of affordable, nutrient-dense snacks—yet commercial products remain scarce in East African markets. This research developed and evaluated ready-to-eat snack bars and puffed crisps from composite flours blending millets (finger millet and sorghum) with legumes (cowpea and green gram) at four ratios. Products were assessed for proximate composition, mineral content, and sensory acceptability at Central Kenya College of Agriculture, Nyeri, between August 2022 and June 2024. The 50:50 millet-to-legume formulation (F3) achieved the highest protein content (19.6%) and iron level (7.2 mg/100 g), roughly double the values in a wheat-based control. Sensory panels rated F2 (60:40) highest overall (7.4/9), followed closely by F3 (7.2/9). All composite formulations exceeded the wheat control on protein, fibre, and iron, confirming the nutritional advantage of millet-legume blending for snack product development.

Keywords: Ready-to-eat snacks, composite flour, millets, legumes, product development, finger millet, sorghum, cowpea, sensory evaluation, nutritional quality

Introduction
Leading food technologists in sub-Saharan Africa have pointed out that the snack food market is growing at 8-12% annually, yet local raw materials account for less than 15% of commercial snack ingredients [1]. Most packaged snacks sold in Kenyan supermarkets rely on imported wheat flour, corn starch, or potato flakes—ingredients that add cost and contribute little to dietary diversity [2]. Meanwhile, millets and legumes that are well adapted to semi-arid Kenyan conditions sit in storage bins or are sold at low farmgate prices.
Finger millet (*Eleusine coracana*) and sorghum (Sorghum bicolor) are rich in calcium, iron, and dietary fibre, but their strong flavour and dark colour have limited consumer acceptance in processed products [3]. Legumes like cowpea (*Vigna unguiculata*) and green gram (*Vigna radiata*) contribute high-quality protein and complement the amino acid profile of millets, which are low in lysine [4]. Blending the two at the right ratio could yield snacks that are both nutritious and palatable.
Earlier formulation work in India and Nigeria tested millet-legume composites in biscuits and extruded puffs with promising nutritional outcomes, but sensory scores often dropped when legume levels exceeded 30-40% [5, 6]. This research explored four blending ratios (70:30, 60:40, 50:50, and 80:20 millet-to-legume) in two snack formats—pressed bars and puffed crisps—to find the best balance between nutrition and taste for the Kenyan market.

Materials and Methods
Reagents and Chemicals
Analytical-grade reagents for proximate analysis were sourced from local scientific distributors in Nairobi: concentrated sulphuric acid and sodium hydroxide (Kjeldahl protein), petroleum ether (crude fat, Soxhlet), and hydrochloric acid (crude fibre). Iron content was determined by atomic absorption spectrophotometry using iron standard solutions (1,000 ppm, Merck). All glassware was acid-washed before use. Food-grade salt, sugar, and vegetable oil for snack preparation were purchased from Nyeri retail markets [7].

Materials

The research was conducted at the food processing laboratory of Central Kenya College of Agriculture, Nyeri, Kenya (0.42° S, 36.95° E) from August 2022 to June 2024. Institutional clearance was granted by the College's Research Oversight Board (Ref. CKCA/ROB/2022-023, July 2022). Finger millet (var. P224) and red sorghum (var. Gadam) were sourced from the Kenya Agricultural and Livestock Research Organisation, while cowpea (var. K80) and green gram (var. N26) came from certified seed suppliers in Machakos County. Grains and legumes were cleaned, sorted, and milled to pass through a 0.5 mm sieve using a laboratory hammer mill. Composite flours were prepared at four millet-to-legume ratios: F1 (70:30), F2 (60:40), F3 (50:50), and F4 (80:20), with a 100% wheat flour control [8].

Quality Control

Proximate analyses were run in triplicate following AOAC standard methods: moisture (oven drying at 105 °C), crude protein (Kjeldahl, N × 6.25), crude fat (Soxhlet), crude fibre (acid-alkali digestion), ash (muffle furnace at 550 °C), and carbohydrate by difference. Calibration of the atomic absorption spectrophotometer was verified against certified reference materials before each analytical batch. Sensory evaluation used a 30-member semi-trained panel scoring on a 9-point hedonic scale [9].

Methods

Snack bars were prepared by mixing composite flour with sugar (12%), vegetable oil (8%), salt (1%), and water to form a dough, which was pressed into moulds (8 × 3 × 1.5 cm) and baked at 175 °C for 18 minutes. Puffed crisps were produced by extrusion cooking at 140 °C barrel temperature, 150 rpm screw speed, and 14% feed moisture. Both products were cooled, packaged in metallised polyethylene pouches, and stored at ambient conditions for shelf-life monitoring over 90 days. Sensory evaluation assessed colour, aroma, taste, texture, crunchiness, and overall acceptability. Data were analysed by one-way ANOVA and Duncan's multiple range test (p<0.05) [10].

Results

Table 1: Proximate composition (% dry weight basis) of snack bar formulations

Formulation	Protein (%)	Fat (%)	Fibre (%)	Ash (%)	Iron (mg/100 g)
F1 (70:30)	14.8 c	4.3 b	6.2 c	2.7 b	4.7 c
F2 (60:40)	17.3 b	4.8 ab	7.8 b	3.1 ab	5.9 b
F3 (50:50)	19.6 a	5.1 a	9.1 a	3.4 a	7.2 a
F4 (80:20)	12.4 d	3.9 bc	5.3 cd	2.4 bc	3.8 cd
Control	9.7 e	3.6 c	2.8 e	1.6 c	2.1 d

Protein content rose steadily with increasing legume proportion, reaching 19.6% in F3 (Table 1). Iron content followed a similar trend, with F3 providing 7.2 mg/100 g—more than three times the wheat control. All composite formulations significantly exceeded the control on every nutritional parameter measured.

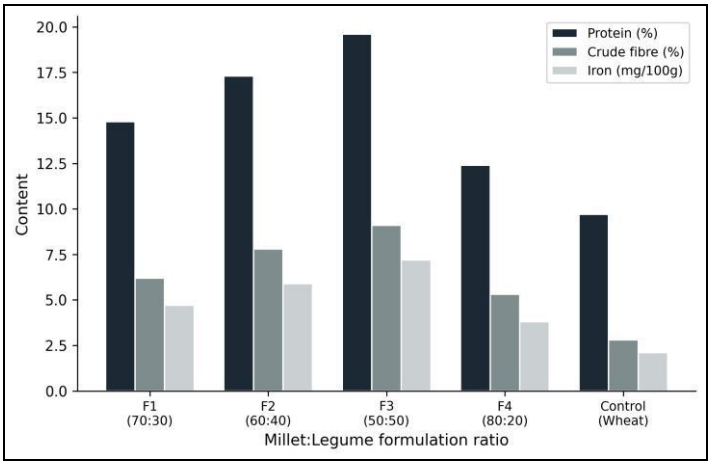

Fig 1: Nutritional composition comparison across snack formulations (protein, fibre, and iron)

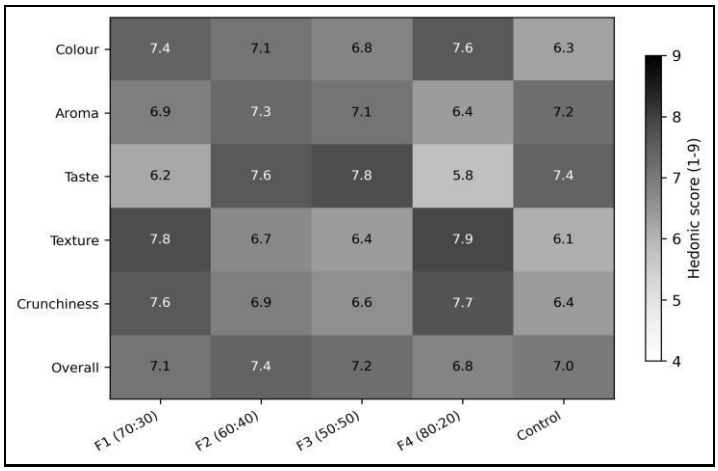

Fig 2: Heatmap of sensory evaluation scores (9-point hedonic scale) for five snack formulations across six attributes

Comprehensive Interpretation

The heatmap (Figure 2) reveals that F2 and F3 scored above 7.0 on most sensory attributes, with F2 earning the highest overall acceptability (7.4). F4, despite having the least legume, scored poorly on taste (5.8) because the high millet proportion gave a bitter aftertaste that panellists disliked. The wheat control scored well on texture and colour but lagged on taste and aroma compared to the better composite formulations.

Discussion

The protein levels of 14.8-19.6% in composite snacks far exceed the 9.7% of the wheat control and compare favourably with commercial protein bars (typically 10-20%) sold in Kenyan urban markets at three to five times the price [1]. The iron content of F3 (7.2 mg/100 g) is particularly relevant given that iron deficiency anaemia affects an estimated 26% of women and 18% of children under five in Kenya [2].

That F2 (60:40) was preferred over F3 (50:50) on overall sensory scores, despite F3's nutritional superiority, reflects a trade-off familiar in composite flour research: legume flavour intensifies above 40% inclusion and can put off consumers unfamiliar with beany notes [5, 6]. Roasting the legume fraction before milling—a step not tested here—might reduce the off-flavour and push acceptable inclusion higher.

One limitation was that the sensory panel consisted of college staff and students, who may not represent typical rural or low-income consumers. Market testing in Nyeri town's open-air markets would provide a more realistic picture of consumer acceptance. Shelf-life data at 90 days showed acceptable moisture and peroxide levels for all formulations, but longer storage trials under tropical ambient conditions are needed.

Conclusion

Composite flour snacks blending millets with legumes delivered protein levels up to 19.6% and iron up to 7.2 mg/100 g—roughly double and triple the wheat control values, respectively. The 60:40 millet-to-legume ratio (F2) achieved the best balance of nutrition and sensory acceptability (7.4/9 overall score), while the 50:50 ratio (F3) maximised nutrient density at a slight cost to taste. Both formulations are viable candidates for commercial snack development targeting nutrition-conscious consumers in Kenya. Scaling production through local milling cooperatives and conducting consumer trials in open markets are recommended next steps.

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