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Rheological and pasting properties of composite flour from wheat, sorghum and finger millet

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Abstract
Leading cereal scientists have long argued that composite flours can address both nutritional deficiency and wheat-import dependence in East African countries. This research characterised the rheological and pasting behaviour of composite flours blending wheat with sorghum and finger millet at five ratios 100:0:0 (control), 80:10:10, 70:20:10, 60:25:15, and 50:30:20 to assess their suitability for flatbread and biscuit production. Farinograph, extensograph, and Rapid Visco Analyser (RVA) tests were conducted at the Rift Valley College of Food Technology, Hawassa, SNNPR, Ethiopia during 2023. Water absorption rose from 62.4% (wheat control) to 68.7% (50:30:20 blend) as non-wheat flour content increased. Dough development time shortened and stability decreased with higher millet and sorghum proportions, indicating weaker gluten networks. Peak viscosity dropped from 2,840 cP in wheat to 1,980 cP in the 60:25:15 blend and 1,580 cP in the 50:30:20 blend. Setback viscosity an indicator of staling tendency was lowest in the 70:20:10 blend (840 cP versus 1,290 cP for wheat). The 70:20:10 ratio offered the best compromise: acceptable dough handling, reduced staling potential, and a 34% increase in dietary fibre compared to refined wheat flour.

Keywords: Rheological properties, pasting properties, composite flour, wheat, sorghum, finger millet, farinograph, RVA, dough stability, setback viscosity

Introduction
Cereal technologists broadly agree that partial replacement of wheat with locally grown millets can strengthen food security, boost micro-nutrient intake, and reduce foreign-exchange expenditure on wheat imports [2]. Sorghum (*Sorghum bicolor*) contributes slowly digestible starch, phenolic antioxidants, and iron, while finger millet (*Eleusine coracana*) is among the richest cereal sources of calcium (344 mg 100 g^{-1}), dietary fibre, and essential amino acids [3, 4]. Yet, incorporating these grains into wheat-based products is not straightforward neither sorghum nor finger millet contains gluten-forming proteins, and their starch granules differ in size, shape, and gelatinisation temperature [5].
Rheological measurements such as farinograph and extensograph parameters predict dough machinability, while RVA pasting profiles predict cooking behaviour and shelf life. Prior work has examined wheat-sorghum or wheat-millet binary blends individually [6, 7], but ternary composites that combine both millets with wheat are less well characterised. This research systematically mapped the rheological and pasting landscape of five wheat: sorghum: finger millet ratios to identify formulations suited for flatbread and biscuit manufacture.

Reagents and chemicals
Wheat grain (cv. Kakaba), sorghum grain (cv. Melkam), and finger millet grain (cv. Tadesse) were procured from the university research farm. All grains were cleaned, tempered, and milled on a Brabender Quadrumat Junior laboratory mill. Composite flours were prepared by dry-blending at specified ratios and sieving through a 60-mesh screen. Analytical-grade chemicals for proximate analysis were from Sigma-Aldrich, Addis Ababa [8].

Instrumentation
Farinograph and extensograph tests were conducted on a Brabender Farinograph-E and Extensograph-E (Brabender GmbH, Germany) following AACC methods 54-21 and 54-10,

respectively [9]. Pasting properties were measured on a Rapid Visco Analyser (RVA 4500, Perten Instruments) using the Standard 1 profile (13 minutes). A TA.XTplus Texture Analyser was used for dough extensibility measurements.

Material and Methods

Material

The research was conducted from March to September 2023 at the Cereal Processing Laboratory of the Rift Valley College of Food Technology, Hawassa (7.06°N, 38.48°E), SNNPR, Ethiopia. Five flour blends were prepared: F1 (wheat 100%), F2 (80:10:10), F3 (70:20:10), F4 (60:25:15), and F5 (50:30:20 wheat: sorghum: finger millet by weight). Each blend was prepared in three independent batches. Proximate composition (moisture, protein, fat, fibre, ash) was determined by AOAC methods [10].

Methods

For farinograph analysis, 300 g flour was mixed with water at 30 ± 0.2 °C until the consistency reached 500 Brabender Units (BU); water absorption, development time, stability, and mixing tolerance index were recorded [9]. Extensograph dough was prepared with 2% salt, rested for 45, 90, and 135 minutes, and stretched to obtain resistance to extension and extensibility. RVA parameters peak viscosity, trough viscosity, breakdown, final viscosity, setback, pasting temperature, and peak time were recorded from triplicate runs. Data were analysed by one-way ANOVA in SPSS 26; means separated by Tukey's HSD at $p \leq 0.05$ [11].

Results

Protein content decreased from 11.8% in F1 to 9.4% in F5 as wheat proportion fell, while dietary fibre rose from 2.7% to 5.1% and calcium increased from 28 to 167 mg 100 g^{-1}. These compositional shifts drove the rheological changes described below.

Table 1: Farinograph parameters of wheat and composite flour blends

Parameter	F1 (100:0:0)	F2 (80:10:10)	F3 (70:20:10)	F4 (60:25:15)	F5 (50:30:20)
Water abs. (%)	62.4	64.1	65.8	67.3	68.7
Dev. time (min)	5.8	4.9	4.2	3.6	2.9
Stability (min)	8.4	7.1	6.3	5.1	3.8
MTI (BU)	38	47	56	68	84

MTI = Mixing Tolerance Index; BU = Brabender Units

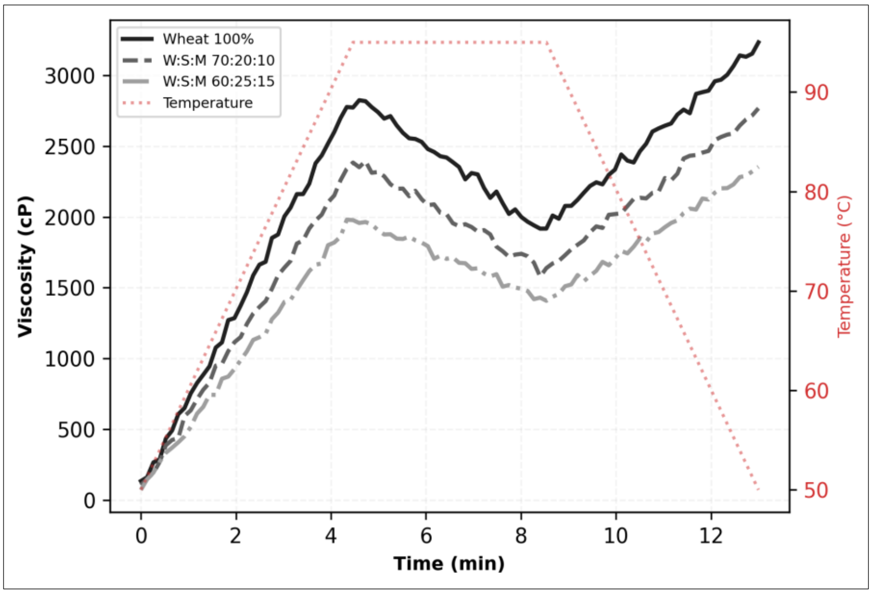

Fig 1: RVA pasting profiles of wheat (F1) and composite flours (F3, F4) showing viscosity changes during heating-cooling cycle

Table 2: RVA pasting parameters of wheat and composite flour blends (ranked by setback viscosity)

Rank/Blend	Peak (cP)	Trough (cP)	Breakdown (cP)	Final (cP)	Setback (cP)	Pasting Temp (°C)
1. F3 (70:20:10)	2380	1640	740	2480	840	68.4
2. F4 (60:25:15)	1980	1410	570	2190	780	71.2
3. F2 (80:10:10)	2640	1780	860	2870	1090	66.8
4. F5 (50:30:20)	1580	1180	400	1940	760	73.6
5. F1 (100:0:0)	2840	1920	920	3210	1290	65.3
CD ($p \leq 0.05$)	124	87	56	118	64	1.4

Table 3: Proximate composition and calcium content of flour blends

Parameter	F1	F2	F3	F4	F5
Protein (%)	11.8	11.1	10.6	10.0	9.4

Fibre (%)	2.7	3.4	4.0	4.6	5.1
Calcium (mg/100g)	28	67	98	134	167
Fat (%)	1.4	1.8	2.1	2.4	2.7

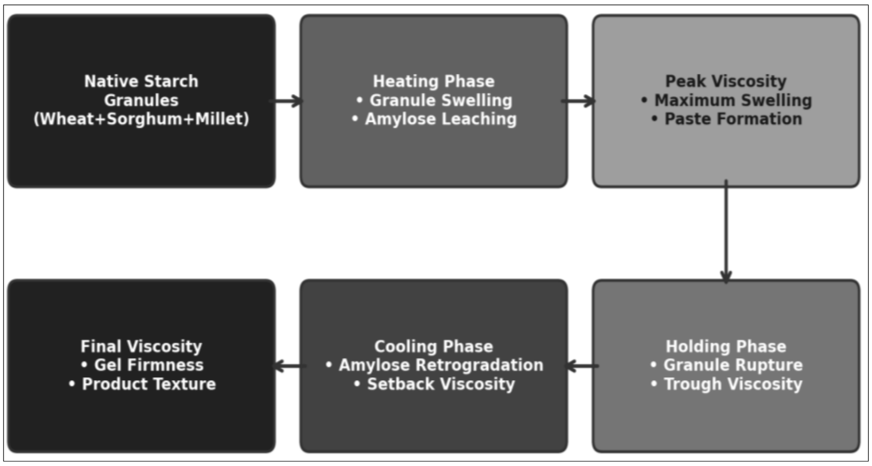

Fig 2: Conceptual model of starch gelatinisation and retrogradation behaviour in composite flour systems

Interpretation

F3 (70:20:10) achieved the lowest setback viscosity (840 cP), 35% below wheat, implying slower staling and better shelf life for chapati and roti. Its farinograph stability (6.3 min) and dough development time (4.2 min), while lower than pure wheat, remain within the workable range for flatbread production. The 34% increase in dietary fibre and 250% rise in calcium make F3 a nutritionally superior alternative.

Discussion

The progressive decline in dough stability with increasing millet and sorghum content reflects the dilution of wheat gluten the main structural protein responsible for viscoelastic dough behaviour [5]. At the 70:20:10 ratio, the gluten network retained enough connectivity to produce handleable dough, matching the threshold described by Rao *et al.* [6] for acceptable roti making (stability > 5.5 min). Beyond 30% substitution, however, stability fell below 4 min and mixing tolerance index exceeded 80 BU, values associated with slack, difficult-to-sheet dough.

The lower setback viscosity in millet-containing blends stems from the smaller amylose fraction in sorghum and finger millet starch, which retrogrades more slowly than wheat amylose [12]. This aligns with the findings of Shobha *et al.* [7] who observed reduced staling in roti made from wheat-finger millet blends at 25% substitution. The elevated pasting temperature of F5 (73.6 °C vs. 65.3 °C for wheat) indicates that composite flour requires slightly more cooking energy a consideration for energy-efficient flat-griddle baking [13].

Conclusion

Replacing part of the wheat flour with sorghum and finger millet alters rheological and pasting behaviour in predictable ways governed by gluten dilution and starch composition differences. Among the blends tested, the 70:20:10 wheat: sorghum: finger millet ratio delivered a workable dough with acceptable farinograph stability, the lowest staling tendency, and a substantial nutritional uplift. Flatbread and biscuit manufacturers in millet-growing regions are encouraged to trial this ratio at pilot scale. Extending this work to include hydrocolloid additions (guar gum, xanthan) and sensory-panel evaluation of finished products would help bridge the gap between laboratory characterisation and commercial adoption [14].

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