Evaluation of functional and rheological properties of the composite flour from oat, wheat and moringa tree leaves

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Abstract: The aim of this research was to evaluate the chemical, functional and rheological properties of the blended flour consisting of wheat, oat and moringa leaves to determine their potential for noodle production. The flour was mixed considering wheat as base flour (control) and taking equal proportions of moringa powder and oat flour at a ratio of 50–100 and 5–50%, respectively. The flour was analyzed for proximate composition (moisture, protein, fiber, fat and ash) functional properties (water and oil absorption capacity, pasting, farinogram and gluten content properties. The protein content was recorded as 11.02 ± 0.03 for wheat flour (C); 13.20 ± 0.02 for oat flour; and 28.75 ± 0.75 for moringa leaf powder. The final viscosity pasting property of the control flour was higher (1896 RVU) and decreased along with increased blending ratios (927RVU) in M₅. The water absorption capacity of flour was increased (39.94 ± 0.07 in M₁ to 41.5 ± 0.50 in M₅) as the amount of blending ratio oat and moringa flour increased, while the oil absorption capacity decreased (39.85 ± 0.23 in M₁, 35.50 ± 0.12 in M₅). The analysis results indicated that the blended flours has shown the better potential to produce noodles of good nutritional value in compared to single wheat flour noodles.

Subjects: Preservation; Processing; Product Development

Keywords: composite flour; wheat; oat; moringa; rheology; water absorption
1. Introduction

As in all developing countries, agriculture is a dominant sector, the basis of the economy and industry, in Ethiopia, contributing to 46 % of the GDP, over 90 % of exports, 83 % of employment opportunities, and supply 70% of the industrial raw materials for domestic industries (Abate, 2018; Dibaba, 2019). Grains have an important place in the agricultural production, and one of the largest grain producers in Africa (AACCSA, 2017). In Ethiopia, cereal crop production and marketing contributes a great role in its economic growth and development, which creates rural employment opportunities (about 60%); more than 40% of a households food expenditure is covered by the income obtained from cereals (Abate, 2018). Wheat is one of the most important cereal crops grown in most parts of Ethiopia, which plays a leading role in both the diet and the economy, and contributes to the major share of daily consumption and cash source (AACCSA, 2017; Dibaba, 2019), and the second largest wheat producer in Sub-Saharan Africa, next to South Africa (AACCSA, 2017). In addition, wheat and wheat products make up 14 percent of the country’s total caloric intake. Ethiopia also imports (25%-35%) a significant amount of wheat for domestic consumption (AACCSA, 2017).

In the pastry and baking industry, wheat flour has been utilized as the single carbohydrate entity for preparation of acceptable pastry and baking products (Pulle & Ino, 1975). However, diminishing of international wheat supplies associated with increasing of marked price (Pulle & Ino, 1975), lacks nutritional components like minerals and dietary fibers from pastry and bakery products produced from wheat flour due to removal of bran during wheat flour preparation (Rani et al., 2018), the increasing awareness of consumers for their diet health benefits and food nutritional constituents (Raihan & Saini, 2017) demanded the use of alternatives for preparation of pastry and bakery items (Pulle & Ino, 1975). Currently, composite flour production is interesting option and has been widely adopted around the world for development of functional foods with the necessary nutritional value and boost health benefits (Awolu et al., 2017) and to the negative effects caused by increasing imports of wheat in non-wheat producing developing countries (Pulle & Ino, 1975).

Several developing countries are also adopting the use of composite flours in bakery and pastry food products to increase health and economic factors and to reduce the cost of wheat imports (Olaoye et al., 2006).

*Moringa oleifera* is found in dry tropics worldwide, and its leaves is the source of vitamins (A, B, and C), and minerals (Sengev et al., 2013). Almost all parts of this tree are suitable for nutritional and commercial purposes as it is rich in nutrient and also used for an antioxidant, anticancer and, anti-diabetic. Lactating mothers are using moringa leave extracts to increase their breast milk for their babies. *m. oleifera* seed is used widely in water treatment (Gopalakrishnan et al., 2016). Oats (*Avena sativa L.*) has good nutritional value as it contains high dietary fiber and phyto-chemicals (Rasane et al., 2015). *Moringa oleifera* and oats are rich in food chemical composition, so they play a big role in the health of our bodies (Getachew & Admassu, 2020). The incorporation of under-utilized plant food sources into food products is a positive, new approach for food security. This research analyzed the chemical, functional, and rheological properties of blended flours of wheat, oat, and moringa leaves to determine their potential for food production.

2. Materials and methods

2.1. Raw materials

The durum wheat (fetan 28) and moringa leaves used in this study were obtained from Ethiopian agricultural research center, Debrezeit, Ethiopia and while the oats collected from the local market.

Sample preparationsThe wheat and oats were manually cleaned to remove coarse impurities, and then washed and soaked in water for 20 minutes for de-hulling. After the bran was removed, the grains were dried in the sun for one day and milled separately using laboratory mill. The
moringa leave was sun dried for three days, and stayed in an air oven at 40°C about six hours. Finally, they were milled by a FRITSCH laboratory disk mill, and all the milled flours were sieved at 150 µm sieve size to keep the size uniformity.

2.2. Preparation of flour blends
The three flours were prepared as composite flour using the blending ratio as indicated in Table 1 to partially substitute the base flour (wheat) up to 50%, while the others are used from 0% to 25% each, making 50% in combination (moringa and oat). The flours were well mixed with the mixer, and the blended flours were kept in an air tight bag for further study.

2.3. Proximate properties analysis
The Moisture content of flours were analyzed according to (AACC44–15.02, 1999). The protein content analysis was determined according to kjeldahl technique (AACC46–11.02, 1999).

\[
\text{% protein} = \frac{(B - S) \times NX\ 1.4007 \times f}{\text{sample weight} \ (g)}
\]

Where

\[
B = \text{volume} \ (\text{ml}) \ \text{of alkali back-titration of blank};
\]
\[
S = \text{volume} \ (\text{ml}) \ \text{of alkali back-titration of sample};
\]
\[
N = \text{normality of alkali}; \ \text{and} \ f = \text{a factor of} \ (6.25)
\]

The fat composition was determined using Solvent Auto Extraction instrument according to method (Thiex et al., 2003). Fiber content was analyzed according to method (AACC32–10.01).

2.4. Functional properties analysis

2.4.1. Water and oil absorption index analysis of the composite flours
Water and oil binding capacity of the flour blend was analyzed as described in the method (Sosulski & Garratt, 2015) by using centurion bench top centrifuges where a gram of sample was mixed with 10 milliliter of distilled water or oil and centrifuged for 30 min at 402 (RFC). The absorption capacity of the flour was recorded as % water or oil absorbing per gram of flour.

2.5. Rheological properties of control and composite flour dough
Rheological properties of control and the blended flours were determined according to method (AACC, .76–21.02, 2007) where 3.5 g sample was mixed with 25 ml of distilled water in rapid visco analyzer machine. The flour dispersions was heated from 50 to 95°C and held at 95°C for 5 min.

| Table 1. Blending ratio of flours to form composite |
|--------------------------------------------------|
| Composite flour constituents                      |
| Treatment            | Wheat flour (%) | Moringa flour (%) | Oat flour (%) |
|----------------------|-----------------|-------------------|--------------|
| C                    | 100             | 0                 | 0            |
| M₁                   | 95              | 2.5               | 2.5          |
| M₂                   | 90              | 5                 | 5            |
| M₃                   | 80              | 10                | 10           |
| M₄                   | 70              | 15                | 15           |
| M₅                   | 50              | 25                | 25           |

C: 100% control flour, M₁: 95% wheat, 2.5% oat and moringa flour, M₂: 90% control, 5% oat and moringa flour, M₃: 80% control, 10% oat and 10% moringa flour, M₄: 70% control flour, 15% oat and Moringa flour, M₅: 50% control, 25% oat and moringa flour.
Then, the temperature was cooled to 50°C and held for 2 min. The total time to complete analysis was 13 minutes. The analyzed rheological properties were pasting property, maximum viscosity, trough, breakdown, final viscosity and setback viscosity from the recorded curve.

2.6. Farinograph determination
The Farinogram properties of the blended flours were analyzed according to the method (AACC.54–22.01) using Farinograph-E equipped with a mixing container (Straumite, Sabovics, Kronberga, & Labanovska). Water absorption property, dough development time and dough stability time of control flour and blends were determined.

2.7. Prepare noodle for cooking quality analysis
The noodle was prepared by extruding the control and composite flour dough in the form of short pasta using extruder, and then the noodle was weighed and cooked in boiled water for seven minutes. The residue left after cooking is collected and dried to analyze loss.

2.8. Thermal properties determination
The heating rate properties of composite were analyzed in term of gelatinization, swelling and pasting behavior using rapid visco-analyzer.

3. Statistical analysis
The analysis was performed in triplicate for each treatment and reported by standard deviation statistical analysis was carried out using IBM SPSS software. Significant difference (P< 0.05) test was used to evaluate the effects of mixing ratios on physico-chemical properties of flours. The results were reported by mean and standard deviation.

4. Results and discussion

4.1. Proximate analysis of raw materials
The result of chemical composition of wheat flour, oat and Moringa powder were presented in Table 2 below. The results indicated that Moringa Leaves contained 7.5% ± 0.014 moisture content, 28.75% ± 0.01 protein, 6.91% ± 0.012 fat, and 12% ash. The protein and fat content results were in agreement with previously reported result by (Busani et al., 2011), but moisture and ash content were not in line with this report. The dried moringa oleifera leaves flour has higher food chemical compositions and lower moisture content which helps the elongated shelf life compared to wheat and oat flour; so it could be suggested that moringa oleifera has the potential to increase the food chemical composition when mixed into different food recipes.

As demonstrated in Table 2, durum wheat flour contained 11.5% ± 0.06 moisture content, 11.02% ± 0.09 protein, 1.66% ± 0.13 fat, 1.32% ± 0.07 ash and 2.11% ± 0.05 crude fiber. The results in protein content were in agreement with the result reported by (Offia-Oluwa, 2014). Oat flour contained 11 ± 0.05% moisture content, 13 ± 0.20% protein, 4.46 ± 0.09% fat, 1.6 ± 0.08%, ash and 4.84 ± 0.01% crude fiber. These results in protein and fat content were in agreement with the result reported by (Rasane et al., 2015). This result indicates the dried moringa oleifera leaves and oat flour contain more nutrient composition in compared to wheat flour. Therefore, Moringa leaves and oat flour could improve the quality of noodle proximate properties if blended with wheat flour and they have the potentials to produce nutritious noodles than single wheat flour.

| Table 2. Proximate composition of Wheat, Moringa, and Oat flour (%) |
|---------------------|-----------|-----------|-------|----------|--------|
| Flour samples       | Moisture  | Protein   | Fiber | Fat      | Ash    |
| Wheat               | 11.5 ± 0.06 | 11.02 ± 0.03 | 2.11 ± 0.05 | 1.66 ± 0.13 | 1.32 ± 0.07 |
| Oat                 | 11 ± 0.05  | 13.0 ± 0.20  | 4.84 ± 0.01  | 4.46 ± 0.09  | 1.6 ± 0.08  |
| Moringa             | 7.5 ± 0.07 | 28.75 ± 0.08 | 5.27 ± 0.06 | 6.91 ± 0.12 | 12 ± 0.14  |
4.2. Determination of flour functional properties

4.2.1. Water and oil absorption capacity of flours
Water absorption capacity is the amount of water that binds to flour to get the desired consistency to prepare quality food products. Moringa flour showed higher water absorption (42.5%) than wheat (37.5%) and oat flour (39.15%) as summarized in Table 3 below. Water absorption capacity of flours was increased in increasing blend ratio; this may be due to higher water binding interaction characteristics of oat and moringa flour components than wheat flour. The appropriate water absorption of flour is used to achieve the desired consistency and create a quality end-product.

The oil absorption capacity of flours is the ability of flour to fat absorbing during product processing. The oil absorption capacity is an essential functional property as it plays great role in achieving good mouth feel. As presented in Table 3, the wheat flour as control flour had higher oil absorption content (49%) in compared to oat (46.5%) and Moringa (40.5%). From this result the cereal grains can bind more water molecules than plant leaves (moringa). This is may be depends on the surface polarity of protein constituents of the flour.

4.3. Rheological properties of control and composite dough

4.3.1. Pasting (viscosity) analysis
Pasting properties of the flour dough are commonly analyzed as it is the important parameters of quality characteristics and helps to predict the viscosity nature of the dough. Maximum (peak) viscosity indicates consistency of flour pastes upon heat treatment, which are caused due to the gelatinization of starch upon processing of food (Liang & King, 2003), (Bakare et al., 2016).

As discussed in the Table 4, the peak viscosity value was ranged from 1416RVU for M5 to 1612RVU of C. The maximum peak viscosity was recorded for control flour (C) while minimum value was recorded for M5, and it was observed that the higher the mixing ratios of dried moringa leaves and oat into wheat flour, the more the reduction in peak viscosity of the dough samples. This may be due to the low starch content in moringa leaves and oat flour in compared to wheat. The higher peak viscosity is depend on high starch content of the materials (Ilelaboye, 2019). Flour that forms higher viscosity can bind its components, which helps to prevent losses during cooking. Increasing the blending amount of moringa and oat flours decreases the strength of flour paste and the extent of granule swelling. So it is necessary to mix the optimum amount of oat and moringa flour into wheat to keep bindings of components during cooking. Trough (holding viscosity) was decreased with increased substitution of moringa and oat. Maximum trough value was

| Thr 3. Centrifugal water and oil absorption analysis of control and blend flour |
|-------------------------------|-----------------|------------------|
| Flour samples               | Water absorption (%) | Oil absorption (%) |
| Wheat flour                  | 37.50 ± 0.12     | 49.00 ± 0.16     |
| Oat flour                    | 39.15 ± 0.08     | 46.50 ± 0.13     |
| Moringa flour                | 42.50 ± 0.21     | 40.50 ± 0.12     |
| M1                           | 39.94 ± 0.07     | 39.85 ± 0.23     |
| M2                           | 40.65 ± 0.23     | 39.10 ± 0.18     |
| M3                           | 41.00 ± 0.09     | 39.00 ± 0.06     |
| M4                           | 41.20 ± 0.15     | 37.50 ± 0.27     |
| M5                           | 41.50 ± 0.24     | 35.50 ± 0.12     |

C: 100% control flour. M1: 95% wheat, 2.5% oat and moringa flour. M2: 90% control, 5% oat and moringa flour. M3: 80% control, 10% oat and 10% moringa flour. M4: 70% control flour, 15% oat and Moringa flour. M5: 50% control, 25% oat and moringa flour.
808 RVU for C and the minimum was 374 RVU for M₅ (wheat: moringa: oat, which is 50:25:25) blended composite. Holding viscosity measures the capacity of the starch constituents to obtain their gelatinized structure at 95°C under shearing stress. Wheat had a higher strength to maintain its gelatinized shape, but decreased as amount of substitution increased. Maintaining the gelatinized structure means that the flour does not easily lose its structure as heat raise especially during processing into the product, so maximize degree of substitution cause the loss of the structure of starch which may affect the texture of produce.

The breakdown viscosity ranged from 804 RVU for wheat (control) to 1117 RVU for M₄ (wheat: moringa: oat, which is 70:15:15) blended composite. The maximum recorded breakdown viscosity was appeared for blends of M₃ and the lowest value was occurred in the control flour. Breakdown viscosity indicates the ability of the paste to withstand higher temperature during processing. Higher breakdown in viscosity means the starch can’t withstand heat and shear force (Adebowale et al., 2005). Higher breakdown value means the starch granules lost during hot shearing while minimum breakdown values indicates that the starch maintains binding properties (Chinma et al., 2010). The control flour has shown the higher hot paste and shear stability in compared to blend flours.

The final viscosity value was varied from 927 RVU in M₅ to 1896 RVU in control (C), while the setback viscosity value ranged from 553 RVU M₅ to 1088 RVU in C.

Final viscosity shows the capability of the flour sample to form a gel upon heat processing while Set back viscosity is related to gel constancy for retro-gradation. Setback value is also indicates tendency of the starch constituents to be dissolved in hot paste and restore their structure upon cooling (Niba et al., 2002). Chad higher both final and setback viscosity while M₀ obtain minimum. Final and setback viscosity were lowered based on increased in blending of the dried moringa leaves and oat flour; These results may occurred due to the alterations in chemical and nature of bonding behavior in blended flour components (Radley, 2012).

Peak duration was the time when peak viscosity was registered. The value was ranged from 5.33 min to 6.2 min. Wheat flour attained peak viscosity earlier and compared to blend flour; this indicates wheat products require less cooking time.

In general, blending of oat and moringa oleifera flour into wheat flour showed optimum range values of pasting properties when compared with previously reported works, however, high amount mixing ratio of moringa and oat into wheat flour showed lower thermal properties than the control flour. Therefore, it is important to blend moringa and oat into wheat flour for better noodles and different food product development.

| Blended flour samples | Peak viscosity (RVU) | Holding time (min) | Breakdown viscosity (RVU) | Final viscosity (RVU) | Setback viscosity (RVU) | Peak time (min) |
|-----------------------|----------------------|--------------------|--------------------------|-----------------------|------------------------|----------------|
| C                     | 1612 ± 0.13          | 808 ± 0.21         | 804 ± 0.27               | 1896 ± 0.43           | 1088 ± 0.70            | 5.33 ± 0.08    |
| M₁                    | 1607 ± 0.15          | 706 ± 0.26         | 1101 ± 0.19              | 1648 ± 0.34           | 942 ± 0.35             | 6.13 ± 0.13    |
| M₂                    | 1572 ± 0.08          | 637 ± 0.31         | 1087 ± 0.34              | 1524 ± 0.40           | 887 ± 0.56             | 6.2 ± 0.22     |
| M₃                    | 1508 ± 0.18          | 603 ± 0.29         | 905 ± 0.28               | 1447 ± 0.37           | 844 ± 0.62             | 6.07 ± 0.26    |
| M₄                    | 1618 ± 0.13          | 501 ± 0.30         | 1117 ± 0.23              | 1245 ± 0.33           | 744 ± 0.39             | 6.07 ± 0.18    |
| M₅                    | 1416 ± 0.21          | 374 ± 0.35         | 1042 ± 0.27              | 927 ± 0.41            | 553 ± 0.59             | 5.93 ± 0.20    |
| M₆                    | 100% control flour.  |                    |                          |                       |                        |                |
| M₇                    | 95% wheat, 2.5% oat  |                    |                          |                       |                        |                |
| M₈                    | 90% control, 5% oat  |                    |                          |                       |                        |                |
| M₉                    | 80% control, 10% oat |                    |                          |                       |                        |                |
| M₁₀                   | 70% control flour, 15% oat and Moringa flour |                  |                          |                       |                        |                |
| M₁₁                   | 50% control, 25% oat |                    |                          |                       |                        |                |
| M₁₂                   | 25% oat and moringa flour |                  |                          |                       |                        |                |

C: 100% control flour, M₁: 95% wheat, 2.5% oat and moringa flour, M₂: 90% control, 5% oat and moringa flour, M₃: 80% control, 10% oat and 10% moringa flour, M₄: 70% control flour, 15% oat and Moringa flour, M₅: 50% control, 25% oat and moringa flour.
4.4. Farinograph analysis result

Farinograph analysis is frequently used for flour quality analysis. It is used to calculate the amount of water needed to make the dough and also it evaluates the effects of constituents on mixing properties.

Water absorption of control wheat flour was recorded as (55.6 %) which is in agreement with the result reported by (Bakare et al., 2016). However, mixing dried Moringa leaves and Oat flour in to wheat showed a slight decrease in water absorption from 55.6% in C to 55% in M9. The major factors that contribute to such farinograph results may include; protein content, starch, and gluten strength. The trend shown in decreasing of water absorption depends on a complex interaction among flour components.

As indicated in the Table 5, the water absorption capacity was 55.4 in M1, 55.3 in M2 and M3, and 55.1 in M6. Development time is an indication of interactions among flour components during the mixing process. It is basic parameter as it indicates the time when water is added initially and time when the dough attain optimum elastic and viscous property. Short time arriving at the consistency line indicates faster absorption of water and earlier dough development. Dough development time fluctuated from 2.3 minute in C to 3.1 minute in M2 and M3. M1 had faster water uptake and development time 2 minutes, both M2 and M3 had 2.9 minutes while M9 had 3.1 minute dough development time which is lower water uptake compared to C and M9, this may occur due to interaction behavior between elements of flours.

Dough stability is the time needed for the dough to attain the maximum consistency, it is the time when the dough consistency is >500 FU. Dough Stability time shows constancy of the flour during mixing. C had a 0.9 minutes dough stability time, 1.8 minutes for M6 while both M1 and M2 had a higher dough stability time value of 3.9 minutes compared to C and M6. From this result, it can be concluded that wheat flour had lower stability over processing compared to blended flour. Blend flour at (2.5% and 5%) are tolerant to the mixing process but as percentages of blending increased the stability of the dough decreased, this may have resulted from flour properties. These results indicate wheat, oat and moringa composite flour has relatively good farinograph properties of dough for noodles production.

4.5. Extruded noodle products and their cooking qualities

Cooking quality of noodles shows its strength to maintain its structure upon cooking. It is measured by amount of residue left in the water after cooking (Figure 1). The lower residue means the product has better quality. The cooking loss of developed noodles was varied. The cooking stability of noodle prepared from control flour was related to the result obtained by (Sobota & Zarzycki, 2013; 5.8 ± 0.36).

| Table 5. Farinograph properties analysis of control and blend flour |
|---------------------------------------------------------------|
| **Flour samples** | **Water absorption (%)** | **Development time (min)** | **Stability time (min)** | **Consistency (FU)** |
|-------------------|--------------------------|----------------------------|--------------------------|----------------------|
| C                 | 55.6 ± 0.06              | 2.3 ± 0.05                 | 0.9 ± 0.08               | 482 ± 0.25           |
| M1                | 55.4 ± 0.13              | 2.9 ± 0.16                 | 3.9 ± 0.07               | 511 ± 0.29           |
| M2                | 55.3 ± 0.09              | 2.9 ± 0.32                 | 3.9 ± 0.13               | 516 ± 0.27           |
| M3                | 55.3 ± 0.07              | 3.1 ± 0.24                 | 2.9 ± 0.15               | 501 ± 0.22           |
| M6                | 55.1 ± 0.14              | 2.5 ± 0.08                 | 1.5 ± 0.06               | 393 ± 0.30           |
| M9                | 55.2 ± 0.22              | 2 ± 0.23                   | 1.8 ± 0.11               | 499 ± 0.19           |

C: 100% control flour. M1: 95% wheat, 2.5% oat and moringa flour. M2: 90% control, 5% oat and moringa flour. M3: 80% control, 10% oat and 10% moringa flour. M4: 70% control flour, 15% oat and Moringa flour. M5: 50% control, 25% oat and moringa flour.
The results of cooking quality were indicated in Table 6. Cooking quality was decreased with increasing blending ratios. This might occur because of lowering gluten content with blends increasing. Water uptake index is the amount of water bind to noodle after draining. The water binding of the noodle raised as the mixing ratio elevates. M₅ bind more water compared to the control noodle had a lower, this is may be due to the moringa and oat proteins binds to water well upon cooking.

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5. Conclusion
The blend of wheat, moringa and oat flour have relatively better proximate and functional properties. The chemical compositional analysis indicated incorporating wheat flour with moringa and oat flour could have better potential in producing nutritious noodle products, because the analyzed properties showed better result in blending of wheat flour with dried moringa leaves and oat flour.

Generally, blends of wheat, oat, and moringa oleifera had good potentials for noodle production. Consumption of noodle foods produced from this composite flour will increase nutritional and health benefits of an individual.

Table 6. Cooking acceptance of extruded noodles

| Samples | Water uptake index (%) | Cooking loss (%) | Cooking time (min) |
|---------|------------------------|------------------|-------------------|
| C       | 47.71 ± 0.07           | 6.32 ± 0.13      | 7                 |
| M₁      | 48.53 ± 0.05           | 6.51 ± 0.17      | 7                 |
| M₂      | 49.74 ± 0.14           | 7.40 ± 0.23      | 7                 |
| M₃      | 51.60 ± 0.09           | 8.89 ± 0.22      | 7                 |
| M₄      | 55.27 ± 0.11           | 10.60 ± 0.25     | 7                 |
| M₅      | 56.41 ± 0.17           | 11.87 ± 0.26     | 7                 |

C: 100% control flour. M₁: 95% wheat, 2.5% oat and moringa flour. M₂: 90% control, 5% oat and moringa flour. M₃: 80% control, 10% oat and 10% moringa flour. M₄: 70% control flour, 15% oat and Moringa flour. M₅: 50% control, 25% oat and moringa flour.
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