Research Article

Fermentation Dynamics of Ethiopian Traditional Beer (Tella) as Influenced by Substitution of Gesho (Rhamnus prinoides) with Moringa stenopetala: An Innovation for Nutrition

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1. Introduction

Tella is an Ethiopian traditional fermented beer-like beverage made from varieties of cereals and a herb locally called gesho (Rhamnus prinoides). Tella resembles commercial beer in that it is made of malted barley and other grains, with the addition of gesho as a traditional hop [1]. Tella is a predominant traditional alcoholic drink consumed in almost every region of Ethiopia, but more popular in the central and northern parts of the country [2]. A variant of tella known as karibo, which is made without the addition of the herb gesho and brief fermentation, is also common among the Muslim families in Ethiopia [3]. Tella is still widely consumed on special occasions like holidays and wedding ceremonies in urban areas [4]. It is part of the staple foods of rural families during the busy farming seasons as refreshing and energy drink among the rural communities. Tella is known by different names among the Ethnic groups in Ethiopia, which includes ኩ Cheer in Amharic, Farsoo in Afaan Oromo, and Siwa in Tigrigna. There are also variations in the ingredients and processes of tella making among the different ethnic cultures in Ethiopia [5]. Ingredients and processing methods used by the Amhara mothers in north-western Ethiopia were more common and considered in the current work. With the popularization of industrial beer and soft drinks, the consumption of tella and other traditional beverages is declining. Moreover, a stigmatized view towards tella consumption is developing among urban youth, where people consuming tella are bullied, a sense that tella is a poor or rural peoples’ drink.

Tella is a low alcoholic beverage with an alcoholic range between 2 and ~4.0% or g/100 mL [6], which makes it nutritionally important in the rural community as a low alcoholic and high pro- (basically lactic acid bacteria) and prebiotic dietary fiber contents as it is turbid with suspensions. Tella also makes up the livelihood of a significant number of poor...
women in a petty trade setting [6]. It is therefore important to investigate the processes, properties, and ingredients of such traditional products to improve it and scale to a mechanized commercial processing level. Fermented indigenous foods and beverages are also being subjects of extensive research for popularizations due to the potential roles of involved microbes for probiotics in the search for functional foods. There are recent reports of some positive outcomes of the Ethiopian traditionally fermented foods and beverages [7, 8].

There is therefore an obvious need to improve the nutritional properties of the traditional beverages in line with their likely commercialization in the local and international markets. Looking for more nutritious and cheaper ingredients that can serve multiple purposes is of great importance. In line with this, the current research was designed to substitute gesho (R. prinoides) with Moringa stenopetala, which is reported to have higher concentrations and diversity of micronutrients among herbs used as foods [9–11], which is sometimes called the “miraculous African tree” [9]. Leave powder of M. stenopetala was used to substitute 50–100% of the traditionally used herb (gesho) (R. prinoides) in both kitta- (barley made into a thick flat bread) and Enkuro- (roasted barley flour made into a cake of water and flour) based preparations. Comparisons of microbial activities and physicochemical characteristics at different phases of fermentation were made using control tella. Comparisons of selected micronutrient-dietary minerals at the end of fermentation were carried out.

2. Materials and Methods

2.1. Ingredients. The basic raw materials for tella preparation, which were raw grain barley (Hordeum vulgare), barley malt; leaves and steams of gesho (R. prinoides), were obtained and prepared in Motta town of Gojjam, Amhara Region, Ethiopia, with the help of experienced local women in traditional tella brewing. Moringa (M. stenopetala) leaf powder was purchased from a local supermarket in Hawassa city, Ethiopia. The ingredients were packaged in polyethylene bags and stored under cold and dry conditions until used in further preparation steps.

2.2. Preparation of Ingredients. Barley grain was cleaned and roasted to dark color for modification of the endosperm together with flavor and color development. The roasted barley grain was then milled into flour (locally known as derekot) and packaged into polyethylene bags and stored at room temperature until required for the next processing steps [12]. Barley malt was cleaned and milled, after which it preserved the same way the derekot was stored. The leaves and thin branches of gesho were pounded to a desirable particle size (not too fine), using a wooden traditional mortar and pestle. The powders were also packaged in polyethylene bags and stored at a dry and dark place until required for the next step of tella making. The moringa leaf powder was also stored under the same conditions with gesho.

2.3. Adjunct Preparation Methods for Tella. Tella was made using two commonly used traditional methods: kitta- and enkuro-based preparations. The roasted barley flour was mixed with adequate water to make a sticky dough in the kitta preparations that was baked into thick flat bread on a hot metallic griddle [13]. Kitta was kept to cool and broken into pieces. Kitta pieces were dried and preserved for use in the diñafí (final mix of tella for fermentation) stage of tella fermentation. For the enkuro-based preparations, the roasted barley powder was mixed with a limited amount of water (compared to that of kitta) and kneaded into bolus cakes that was cooked on a hot metallic griddle. Enkuro was then cooled, dried, packaged in a polyethylene bag, and transported to the laboratory for use in the diñafí stage of tella fermentation.

2.4. Tella Processing Phase. Tella processing employs three basic fermentation stages: namely, tejet, tinsis, and difedef [1, 12, 14]. Three types of tejet were made by mixing 100 g of malt and 125 g of (i) gesho leaf powders, (ii) moringa leaf powders, and (iii) 50:50 gesho-moringa mixture and left to ferment for 96 hrs. being covered with a piece of clean cloth (Figure 1). The tejet preparations were divided into two and converted to tinsis by adding 225 g of either kitta or enkuro adjuncts (Section 2.3). The tinsis preparations were also left covered to ferment for another 96 hrs. The fermented tinsis was transformed into the final stage of tella fermentation (diñafí) by adding 900 g of the remaining adjuncts (kitta or enkuro) and diluted to tella with 5 liters of water. The final tella mixture was also left covered for another 96 hrs. of fermentation. The solution was strained with clean muslin cloth to remove bigger suspended impurities and biochemically and sensorially characterized.

2.5. Determination of Microbial Dynamics during Tella Fermentation

2.5.1. Yeast and Mold Counts. Ten grams of samples at tejet, tinsis, and tella stages were separately weighed into a stomacher bag (Lab-Blender 400, Seward Medical, London, England) with 90 mL sterile 0.1% peptone water (Merck) and homogenized for 30 s. The homogenized samples were prepared into dilutions with peptone water, and 0.1 mL of each sample was spread-plated in triplicates on presolidified plates of yeast extract on glucose chloramphenicol (YGC) agar and incubated at 28°C for 5 days [15].

2.5.2. Total Aerobic Mesophilic Count (TAMC). Samples (10 g) of tejet, tinsis, and tella were separately transferred into a stomacher with 90 mL sterile 0.1% peptone water and homogenized for 30 s. The homogenate was separately (0.1 mL) spread-plated in triplicates on presolidified plate count agar (PCA) and incubated at 30°C for 48 hrs. The total aerobic mesophilic count (TAMC) was enumerated, and average microbial loads were reported as log10 colony forming units (CFU) per mL of samples [16].

2.5.3. Lactic Acid Bacteria (LAB). Similar dilution and homogenization protocol to those used for TAMC were employed. LAB from the different preparations and
Figure 1: Flow diagram for tella making depicting the major ingredients and operations.

Figure 2: Biochemical properties of tella for different preparations (a), formulations (b) and fermentation phases (c); LAB: lactic acid bacteria; TAMC: total aerobic mesophilic count; TA: titratable acidity; G: gesho; M: moringa; values are least square means with standard error as error bars and bars with different letters are significantly different (p < 0.05).
formulations were inoculated on Man, Rogosa, and Sharpe (MRS) agar plates and anaerobically incubated at 30°C for 72 hrs. The LAB CFU were counted and reported in a similar form for TAMC (Section 2.5.3).

2.5.4. Enterobacteriaceae. Tella samples of the different formulations and preparations (10 g each) were transferred to a stomacher bag with 90 mL sterile 0.1% peptone water and homogenized for 30 s. Samples of 0.1 mL were spread-plated in triplicates on predried plates of violet red bile glucose (VRBG) agar for Enterobacteriaceae (EB) enumeration and incubated at 30°C for 24 hrs. [16]. The EB CFU were counted and reported in a similar form for the other bacterial groups.

2.6. Determination of Physicochemical Properties of Tella

2.6.1. Determination of pH. The pH of fermented tella was obtained using a digital pH meter. About 10 g of the different samples were weighed in duplicates in a 250 mL beaker and mixed with 20 mL of distilled water. The mixes were stirred for 10 min, and the measurements were taken after calibrating the meter with buffers of known pH (4.0 and 7.0). The rode of the pH meters was thoroughly washed using distilled water in between samples.

2.6.2. Alcohol Content. The specific gravity of the samples from different preparations and formulations was measured using a hydrometer. The alcohol percent by volume (ABV (%)) was estimated by a standard conversion factor based on Association of Official Agricultural Chemists (AOAC) and American Society of Brewing Chemists (ASBC) [17, 18].

2.6.3. Titratable Acidity. Titratable acidity (also called total acidity) measures the total acid concentration in a food. This quantity is determined by exhaustive titration of intrinsic acids with a standard base. Titratable acidity (TA) was determined by titrating 10 g of sample with 0.1 N NaOH using three drops of phenolphthalein as an indicator. Titratable acidity of tella samples was expressed as a percentage of lactic acid [15], given by

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TA (%) = \frac{\text{volume of NaOH}}{\text{sample weight in g}} \times 0.09.
\]

2.6.4. Color. The color of each tella sample was determined using a spectrophotometer (Jenway model 7315, Bibby Scientific, Stone, UK), set at 430 nm. The spectrophotometer was set up in concentration mode to directly calculate the European Brewery Convention (EBC) value.

2.6.5. Turbidity. Turbidity of each sample was determined by haze meter based on the percentage of light detected from the incoming light direction based on the European Brewery Convention (EBC) and ASBC methodologies. Unfiltered beer sample was poured into a test bottle, and a calibrated turbidity meter was used to monitor the turbidity (WGZ-4000, Xinrui, China) [19].

2.7. Nutrient Analysis. Dietary mineral contents of tella were analyzed, to see if the addition of moringa improved the dietary minerals. The digestates were refluxed for 90 minutes until a clear solution was obtained. Dietary minerals including iron, calcium, magnesium, potassium, sodium, and zinc were analyzed using a flame atomic absorption spectrophotometer. Samples (10 mL) were digested in 2 mL of nitric acid.
acid and 2 mL of hydrogen peroxide. Estimations of the minerals were made using the spectrophotometer at specific wavelengths for each element.

2.8. Sensory Acceptability of Tella. A consumer sensory test was used to assess the difference between sensory acceptability of tella from different formulations (gesho versus moringa) under different adjunct preparation methods. Sensory attributes considered included color, aroma, taste, and overall acceptability. Adults (n = 46), who normally consume tella, were recruited and oriented to score the level of liking or disliking the products based on the 5-point hedonic scale, where 5 = like extremely, 4 = like slightly, 3 = neither like nor dislike, 2 = dislike slightly, and 1 = dislike extremely. The panelists have been instructed to cleanse their palates before and between samples. Tella samples were coded with random three-digit numbers and presented to panelists in a random order.

2.9. Experimental Design and Data Analysis. The experiment was designed in a 2 × 3 × 3 factorial arrangement for the biochemical properties, where 2 levels of adjunct preparation (kitta versus enkuro), 3 levels of formulation (100% gesho and 50% and 100% moringa substitution), and 3 stages of fermentation (tejet, tinsis, and difdif) were compared. Similarly, a 2 × 3 factorial with 2 levels of preparation and 3 formulations for dietary minerals and with an additional 3 levels of storage days (1, 5, and 10) were compared using analysis of variance (ANOVA) followed by Tukey’s honestly significant (HSD) mean separation technique. Data were presented in graphs (main effects) and tables (interaction) in the form of least square means with standard errors.

3. Results and Discussions

3.1. Biochemical Dynamics by Fermentation Stages

3.1.1. Microbial and Biochemical Dynamics. The microbial loads (LAB, TACMC, and yeast) and chemical status (pH, TA) are influenced by the formulation and fermentation stages (Figure 2, Table 1). The adjunct preparation method (kitta versus enkuro, Figure 2(a)) did not seem to influence chemical properties, where 2 levels of adjunct preparation (kitta versus enkuro), 3 levels of formulation (100% gesho and 50% and 100% moringa substitution), and 3 stages of fermentation (tejet, tinsis, and difdif) were compared. Similarly, a 2 × 3 factorial with 2 levels of preparation and 3 formulations for dietary minerals and with an additional 3 levels of storage days (1, 5, and 10) were compared using analysis of variance (ANOVA) followed by Tukey’s honestly significant (HSD) mean separation technique. Data were presented in graphs (main effects) and tables (interaction) in the form of least square means with standard errors.
the majority of the biochemical parameters except for the titratable acidity (TA, %). The *kitta* preparation method resulted in higher acid production, which might be due to the differences in the degrees of heating and starch modification. The substitution of *gesho* by moringa favored lactic acid bacteria but limited the growth of yeast (Figure 2(b)), which paralleled the increasing trend of lactic acid concentrations. The highest yeast growth on the other hand corresponded to the 50:50 *gesho*-moringa blends, and there were no clear trends in the total aerobic mesophilic count (TAMC).

The increasing number of log10 CFU of the LAB together with the substitution levels of moringa (0 to 100%) was also accompanied with an increasing concentrations of lactic acid. This is evident that the alcohol production was suppressed by the addition of moringa leaf powder instead of the traditionally used *gesho*, which likely implies that substitution of *gesho* with moringa has better probiotic potential and nutritional relevance. The ranges of the biochemical parameters assessed in the present study for *tella* are in agreement with those previously reported for *tella* [6] and *keribo* [3].

There was no *Enterobacteriaceae* detected in the *tella* samples that indicates a low chance of the product being contaminated by bacteria due to poor hygienic practices. The reason might be the high acidity and alcohol levels that create unfavorable conditions for the growth of pathogens. However, it is always recommended that the maximum possible hygienic and sanitary practices are exercised during the processing and handling of indigenous foods and beverages to safeguard the public.

Significantly different microbial loads and chemical phenomena were observed at the different stages of *tella* fermentation (Figure 2(c) and Table 1). The highest LAB and yeast counts were observed at the *tinsis* stage, likely due to the addition of the adjunct regardless of its type (*kitta* or *enkuro*). However, the pH continued to drop along the three stages of fermentation (*tejet* through *djifaf*), which also twinned the continuously accumulating lactic acid. The declining counts of bacteria (particularly TAMC) and yeast in the *djifaf* phase of fermentation are attributed to the depletion of nutrients and acidifying environment. This presents a probiotic application opportunity as *tella* is consumed without heating after fermentation. The implication is that the addition of moringa plays important nutritional roles (micronutrients [9–11]) and also suppresses yeast activity and promotes LAB, which, coupled with the culture of consuming *tella* unheated after fermentation, creates an opportunity for probiotic application. Further investigations into the nutritional and health beneficial potentials of *tella* and many other indigenous African and Asian foods may present a great opportunity in human nutrition and health.

### Table 2: Shelf life of *tella* for different preparation methods [A], formulations [B], and storage time [C]; values are least square means with standard errors as error bars and those with different connecting letters are significantly different (p < 0.05).

| Variables Yeast (log10 CFU/mL) | pH | TA (%) |
|------------------------------|----|--------|
| **Preparation by formulations** | | |
| *Kitta*, 100% G | 3.01<sup>a</sup> | 4.56<sup>c</sup> | 0.74<sup>c</sup> |
| *Kitta*, 50:50, G:M | 2.73<sup>c</sup> | 4.37<sup>d</sup> | 0.94<sup>c</sup> |
| *Enkuro*, 100% G | 3.05<sup>a</sup> | 4.67<sup>b</sup> | 0.72<sup>c</sup> |
| *Enkuro*, 100% M | 2.86<sup>bc</sup> | 4.37<sup>d</sup> | 0.91<sup>b</sup> |
| SE | 0.0297 | 0.021 | 0.006 |

| **Preparation by storage (days)** | | |
| *Kitta*, 1 | 5.10<sup>a</sup> | 4.83<sup>c</sup> | 0.63 |
| *Kitta*, 5 | 3.63<sup>c</sup> | 4.64<sup>c</sup> | 0.68 |
| *Enkuro*, 10 | ND | 4.43<sup>c</sup> | 0.99 |
| *Enkuro*, 5 | 5.12<sup>a</sup> | 4.83<sup>c</sup> | 0.63 |
| SE | 0.03 | 0.021 | 0.006 |

| **Formulations by storage (days)** | | |
| 100% G, 1 | 5.23<sup>a</sup> | 5.31<sup>bc</sup> | 0.54<sup>e</sup> |
| 100% G, 5 | 3.68<sup>d</sup> | 4.99<sup>b</sup> | 0.55<sup>c</sup> |
| 100% G, 10 | ND | 4.61<sup>d</sup> | 0.75<sup>d</sup> |
| 50:50, G:M, 1 | 5.23<sup>a</sup> | 4.65<sup>cd</sup> | 0.59<sup>e</sup> |
| 50:50, G:M, 5 | 3.87<sup>c</sup> | 4.76<sup>c</sup> | 0.62<sup>e</sup> |
| 50:50, G:M, 10 | ND | 4.44<sup>d</sup> | 0.99<sup>b</sup> |
| 100% M, 1 | 4.89<sup>b</sup> | 4.53<sup>bc</sup> | 0.75<sup>d</sup> |
| 100% M, 5 | 3.50<sup>d</sup> | 4.35<sup>bc</sup> | 0.79<sup>e</sup> |
| 100% M, 10 | ND | 4.23<sup>b</sup> | 1.23<sup>a</sup> |
| SE | 0.036 | 0.026 | 0.007 |

Values are least square means with standard error; SE: standard error; G: *gesho*; M: moringa; TA: titratable acidity; CFU: colony-forming units; values are least square means with standard errors as error bars and those with different connecting letters are significantly different (p < 0.05).
3.2. Dietary Minerals of Tella from Different Preparations and Formulations. The main effect of formulation on the dietary mineral contents of tella was statistically meaningful (Figures 4(b) and 4(d)). There was no significant variation in the mineral levels due to the preparation techniques (kitta versus enkuro). The highest mineral contents were observed for the formulation with the 50% substitution of gesho with moringa. The second highest levels of all assessed minerals (except for Zn) were recorded for the 100% substitution of gesho with moringa, indicating that moringa has a higher mineral concentration than gesho. The increase in the concentrations of Ca and Mg minerals in the 50% substitution of gesho with moringa was higher than just the summation of the two herbs, which indicated a type of synergistic effect of interest (Figures 4(a) and 4(c)). The increased levels of the two minerals more than the sum of the two present a great nutritional desirability of blended gesho and moringa in tella preparation. The increased levels of Ca and Mg open an interesting research dimension in tella and other ethnic foods of similar preparations.

Considering the interactions of preparation methods with the formulations, the Zn, Ca, Mg, Na, K, and Fe ranged from (mg L⁻¹) 0.81 to 1.20, 4.76 to 9.96, 3.16 to 7.21, 61.22 to 120.67, 250 to 320, and 0.008 to 0.030, respectively (Table 3). The formulation with the 50% gesho substitution with moringa (50:50 gesho-moringa blend) exhibited higher levels of mineral concentrations in a consistent trend regardless of the adjunct preparation (kitta or enkuro). Ca and Mg concentration obtained from tella samples in the current work was lower, and K and Na levels were higher than the values reported by Tekle et al. [6]. The difference might be due to the variations in ingredients.

The results from the current research are generally promising as a means of nutritional intervention in communities with significant practices of tella consumption. The result also presented a great lesson of dietary interventions for addressing micronutrient deficiencies of the Ethiopian population residing in the central and northern parts of the country, which makes up the vast majority of the Orthodox Christians, often falling short of micronutrient intakes due to recurrent fasting practices [20].
3.3. Sensory Acceptability of Tella from Different Preparations and Formulations. The sensory acceptability of tella samples was significantly influenced by the adjunct preparation methods (color) and formulations (Table 4). Kitta-based tella had a higher score for color than the enkuro-based counterpart. The other sensory attributes (aroma, taste, and overall acceptability) remained unaffected by adjunct preparation methods.

The formulations also influenced the sensory preference of tella samples. Tella samples made from 100% gesho and those with 50% moringa substituting gesho, were better liked in terms of the sensory attributes considered. The comparatively lower scores of samples with 100% moringa might be due to the completely new and unfamiliar sensory profiles coming from moringa.

Looking at the interactions of preparation methods and formulations, kitta-based tella with 100 gesho (traditional control) and 50% substituted by moringa had better preference than the rest although there was no clear statistical segregation. The general evaluation of the tella samples was that all samples were liked by consumers with scores for overall acceptability ranging from 3.16 to 4.41. The overall average scores of the tested sensory parameters were 3.94 on the scale of 5 being the best (like extremely) and 1 being the poorest (dislike extremely).

The result implies that substitution of gesho (less nutritious, at least not well characterized), with moringa, that is, a well characterized crop and reportedly superior nutritionally, can be a sound and acceptable strategy as a local dietary intervention in areas with micronutrient challenges in Ethiopia. The research also documented lessons to improve the nutritional and probiotic functionalities of popular indigenous diets in African and elsewhere.

4. Conclusion

The substitution of gesho with a more nutritious leaf of moringa resulted in products of higher nutritional contents.

### Table 3: Dietary mineral contents of tella samples as influenced by preparation and formulation.

| Variables | Zn (mg/L) | Ca (mg/L) | Mg (mg/L) | Na (mg/L) | K (mg/L) | Fe (mg/L) |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Preparation by formulations |          |           |           |           |           |           |
| Kitta, 100% G | 1.07<sup>b</sup> | 4.76<sup>c</sup> | 3.17<sup>c</sup> | 61.26<sup>c</sup> | 300<sup>b</sup> | 0.008<sup>a</sup> |
| Kitta, 50:50, G:M | 1.20<sup>a</sup> | 9.88<sup>a</sup> | 7.21<sup>a</sup> | 120.67<sup>a</sup> | 320<sup>a</sup> | 0.026<sup>a</sup> |
| Kitta, 100% M | 0.81<sup>c</sup> | 6.52<sup>c</sup> | 4.31<sup>b</sup> | 100.32<sup>b</sup> | 250<sup>c</sup> | 0.019<sup>b</sup> |
| Enkuro, 100% G | 1.07<sup>b</sup> | 4.78<sup>c</sup> | 3.16<sup>c</sup> | 61.22<sup>c</sup> | 300<sup>b</sup> | 0.008<sup>a</sup> |
| Enkuro, 50:50, G:M | 1.20<sup>a</sup> | 9.96<sup>a</sup> | 7.15<sup>a</sup> | 120.67<sup>a</sup> | 320<sup>a</sup> | 0.030<sup>a</sup> |
| Enkuro, 100% M | 0.81<sup>c</sup> | 6.51<sup>b</sup> | 4.31<sup>b</sup> | 100.32<sup>b</sup> | 250<sup>c</sup> | 0.020<sup>b</sup> |
| SE | 0.011 | 0.041 | 0.0196 | 0.158 | 0.038 | 0.0009 |

Values are least square means with standard error; SE: standard error; G: gesho; M: moringa; values are least square means with standard errors as error bars and those with different connecting letters are significantly different (p < 0.05).

### Table 4: Sensory acceptability of tella from the different preparations and formulations.

| Variables | Color | Aroma | Taste | OA |
|-----------|-------|-------|-------|----|
| Preparations |       |       |       |    |
| Kitta        | 4.47<sup>a</sup> | 3.82<sup>a</sup> | 3.75<sup>a</sup> | 3.92<sup>a</sup> |
| Enkuro       | 4.24<sup>b</sup> | 3.77<sup>a</sup> | 3.62<sup>a</sup> | 3.94<sup>a</sup> |
| SE           | 0.055 | 0.06  | 0.066 | 0.06 |
| Formulations |       |       |       |    |
| 100% G       | 4.38<sup>ab</sup> | 4.23<sup>a</sup> | 4.07<sup>a</sup> | 4.24<sup>a</sup> |
| 50:50, G:M   | 4.46<sup>a</sup> | 4.27<sup>a</sup> | 4.17<sup>a</sup> | 4.33<sup>a</sup> |
| 100%M        | 4.23<sup>b</sup> | 2.88<sup>b</sup> | 2.80<sup>b</sup> | 3.22<sup>b</sup> |
| SE           | 0.067 | 0.073 | 0.080 | 0.073 |
| Preparation by formulations |       |       |       |    |
| Kitta, 100% G | 4.53a | 4.30<sup>a</sup> | 4.05<sup>a</sup> | 4.07<sup>a</sup> |
| Enkuro, 100% G | 4.23<sup>ab</sup> | 4.16<sup>a</sup> | 4.086<sup>a</sup> | 4.41<sup>a</sup> |
| Kitta, 50:50, G:M | 4.55a | 4.35<sup>a</sup> | 4.41<sup>a</sup> | 4.41<sup>a</sup> |
| Enkuro, 50:50, G:M | 4.37<sup>ab</sup> | 4.20<sup>a</sup> | 3.94<sup>a</sup> | 4.23<sup>a</sup> |
| Kitta, 100% M | 4.34<sup>ab</sup> | 2.81<sup>b</sup> | 2.79<sup>b</sup> | 3.27<sup>b</sup> |
| Enkuro, 100% M | 4.12<sup>b</sup> | 2.96<sup>b</sup> | 2.82<sup>b</sup> | 3.16<sup>b</sup> |
| SE           | 0.099 | 0.11  | 0.11858044 | 0.11 |

Values are least square means with standard error; SE: standard error; OA: overall acceptability; values are least square means with standard errors as error bars and those with different connecting letters are significantly different (p < 0.05).
The substitution of *gesho* with moringa also suppressed the activity and counts of yeast cells, suppressing alcohol production and favoring LAB activity and lactic acid production. This enhanced the probiotic potential of *tella*, leaving it appealing to the nutrition of adults in central and northern Ethiopia. A 50% substitution of *gesho* with moringa resulted in *tella* of higher nutritional (dietary minerals) and sensory acceptability.

**Data Availability**

The data presented in this study are available on request to authors.

**Additional Points**

*Practical Application.* The research characterized the improvements of *tella* formulations by substituting *gesho* (*Rhamnus prinoides*) with *Moringa stenopetala*. The research examined other potential applications of *tella* as a functional food and to transform it from ethnic beverages towards commercial level production and promotion as *tella* is a naturally fermented product with no heating involved after fermentation. This makes *tella* a probiotic beverage and the substitution of the herb *gesho* with moringa leaves to shift the fermentation from alcoholic to lactic acid by suppressing the growth of yeast and enhancing the growth of lactic acid bacteria. This shift in fermentation dynamics was achieved in addition to improving its micronutrient dietary mineral levels. The research presents promising results that develop a traditional beverage into a commercially viable functional food.

**Consent**

Informed consent was obtained from all sensory panelists involved in the study.

**Disclosure**

A version of this manuscript is previously submitted to Preprint (https://www.preprints.org/manuscript/202105.0773/v1) [12]. The researchers wanted to have the results of this research documented in a peer reviewed journal and decided to submit it here. Proper citations of the version on preprint were also made.

**Conflicts of Interest**

The authors declare no conflict of interest of any sort.

**Authors’ Contributions**

Mr. AMB initiated the proposal in consultation with the other two and collected the data; Dr. TFT analyzed the data with Mr. AMB and wrote the manuscript text and contributed to the graphics; Mr. TBL contributed in shaping the proposal and edited the final write-up.

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