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Research article

Effects of fermentation and malt addition on the physicochemical properties of cereal based complementary foods in Ethiopia

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ABSTRACT

Complementary foods (CFs) in Ethiopia are characterised by bulkiness, and poor nutrient density as these foods are primarily made of starchy staples. Meanwhile, several modification techniques are available to improve the quality of the starch-based CFs. The objective of this study was to examine the effect of fermentation time and malt concentration on cereal-based CFs in Ethiopia, intending to improve the nutrient density and reduce dietary bulkiness. Oats, barley and teff flours, with added malt at different concentrations (0, 2 and 5%), were spontaneously fermented for 0, 24 and 48 h. The physical, chemical and sensory properties of the fermented CFs flour were evaluated. The protein, fat, fibre, energy, phytate, tannin, bulk density, water absorption capacity (WAC) and viscosity ranged between 8.12–16.82%, 1.63–4.55%, 1.58–5.96%, 359.33–380.26kcal/100g, 18.63–175.07mg/100g, 0.84–42.89mg/100g, 0.66–0.99 g/ml, 61.33–143.12%, 235cP-1016.33cP, respectively. For all the three kinds of cereal, fermentation for 24 h resulted in a better sensory quality regardless of the malt concentration. Crude fibre, crude fat, total carbohydrate, phytate, tannin, bulk density and viscosity of the three kinds of cereal were significantly reduced due to the interaction of fermentation and addition of malt. Conversely, crude protein and calorific value were significantly increased by the interaction. Addition of 2% malt and fermentation of the cereal flours for 24 h increased energy density and palatability, reduced dietary bulkiness and viscosity of CFs, which in turn will increase food intake by infants and young children.

1. Introduction

Malnutrition during childhood is among the top public health challenges in low and middle-income countries (LMIC), including Ethiopia (Faruque et al., 2008). Once a baby reaches the six months old mark, his or her nutritional requirement cannot be met by breast milk alone (Adenuga, 2010). Complementary foods (CFs) should be introduced to maintain a child's optimal growth (Nandutu and Howell, 2009).

CFs in the Sub Saharan African region are characterised by low nutrient density (Badau et al., 2005). Bulkiness and high viscosity of the cereal-based CFs are partly associated with the highest rates of malnutrition reported in cereal-based consuming areas of Africa. Mothers reduce the viscosity of such CFs by diluting it with water (Bukusuba et al., 2008). Infants and young children are unable to get the required amounts of nutrients through the consumption of diluted porridge due to their small gastric capacities; as a result, they become malnourished (Ramakrishna et al., 2006).

Several methods are available to increase nutrient density and reduce dietary bulk in the cereal-based CFs. One of the methods is fermentation. Natural fermentation is one of the oldest food preparation methods in Africa responsible for improving the bioavailability of nutrients in plant-based foods (Adebiyi et al., 2018). Further, fermentation lowers the PH, which is responsible for increasing the storage stability of the given food (Khetarpaul and Chauhan, 2007).

Another method is the addition of malt to the CFs. Malt is rich in the enzyme alpha-amylase, which hydrolyses large polysaccharides like starch to glucose and maltose improving digestibility. The addition of amylase-rich flour also intensely reduces the bulk density and viscosity of CFs, transforming them to nutrient-dense liquefied food that can be conveniently ingested by young children (Afoakwa et al., 2010).

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Therefore, this study aims to assess different fermentation periods and malt concentrations on three kinds of common cereal grains used for making CFs in Ethiopia.

2. Materials and methods

2.1. Experimental materials and sample preparation

The experimental materials used for the study were Oats, barley, teff and malt. Oats (Sinana 01) was collected from Sinana Agricultural Research Center, barley (BH-1307) from Holeta Agricultural Research Centre, teff (Kuncho) from Debre Zeit Agricultural Research Centre, and malted barley (Holker) for amylase rich flour (ARF) preparation from Assela malt factory.

The grains and malted barley were cleaned manually to remove the husks, damaged grains and extraneous materials. The grain seeds were then dried in a drying oven at 55 °C (Model 400, Memmert, Germany) for 2 h. The dried grains were milled into flour using a grain mill (KARLKOLB D-6072, Dreich, West Germany) and sieved to pass through a sieve of 0.5 mm aperture size. The flour samples were packed in airtight polyethene bags until the next processing step.

2.2. Experimental design and treatments

The experiment had three factors namely cereal type (Oats, Barley and Teff), fermentation period (0 h, 24 h and 48 h) and malt percentage (0%, 2% and 5%). The treatments were arranged in a 3 × 3 × 3 factorial design in three blocks to investigate the main and interaction effects of type of cereal, fermentation period and malt percentage on physical, chemical and sensory properties of CFs. The experiment was replicated three times.

2.3. Fermentation process

The fermentation process was done by the method developed by (Afoakwa et al., 2010) with some modification. Measured quantities of malt flour (0%, 2% and 5%) were added to each of the flour samples. Then, the grain-malt blends were homogenised using a homogeniser. The flour samples were then added to deionised water in a food-grade 2L plastic pail with handle and lid round bucket containers at a concentration of 1:3 (w/v). The flour slurry was allowed to ferment spontaneously at room temperature (20±3 °C) and lasted for 0, 24, and 48 h depending on the treatment. When the fermentation period is over, the water was decanted. The fermented samples were transferred to aluminium trays and dried in convective oven-drier (LEICESTER LE67 5FT, England) at 70 °C for 3–4 h to obtain moisture contents between 7 and 10%. Dried samples were ground with a mill (KARLKOLB D-6072, Dreich, Germany) to pass through a 0.5 mm sieve. The milled samples were packed in airtight polyethene plastic bags until the next processing step.

2.4. Data collection

2.4.1. Proximate composition

The proximate compositions (dry matter basis) of the CF flours were determined following the Association of Official Analytical Chemists (AOAC) methods: moisture (925.10), crude protein (979.09), crude fibre (962.09), crude fat (920.39) and ash (923.03) (AOAC International, 2005). The proportion of these constituents were summed and subtracted from 100 to get the total carbohydrate content. The energy contents of the CF flours were calculated by using energy conversion factors, Atwater factors (Osborne and Voogt, 1978).

2.4.2. Antinutritional factors

The antinutritional factors; phytate and tannin were evaluated in the CFs flour samples. The Phytate determination was done as per the colourimetric method described by Vaintraub and Lapteva (1988). The amount of phytic acid was calculated using a phytic acid standard curve. The condensed tannin determination was conducted according to the method of Maxson and Rooney (1972).

2.4.3. Functional properties

Three functional properties, namely bulk density, water absorption capacity (WAC) and viscosity, were evaluated in this study. The bulk density of the CFs flour was determined by dividing the weight of the sample by its volume after tapping (Adeleke and Odedeji, 2010). The WAC of flour samples was determined as the per cent water bound by one gram dry flour (Sosulski, 1962). The viscosity of gruel samples was determined by using a HAAKE Falling sphere viscometer (D-76227 Karlsruhe, Germany). A glass cylinder was filled with gruel. A sphere of known diameter and density was dropped into the liquid, and the time taken for the ball to travel a calibrated distance of 100 mm was measured. Viscosity was calculated by rearranging Stoke's law (Flude and Daborn, 1982).

2.4.4. Sensory properties

Only nine treatments were selected for sensory analysis to avoid panellist fatigue from evaluating 27 different products. The selection was made by clustering each cereal based on the fermentation period. Then three treatments were selected from each cereal at which high energy (kcal) was recorded. A total of 50 untrained mothers were selected as panellists in this study. The panellists were asked to rank the gruels by appearance, aroma, taste, mouth-feel, consistency and overall acceptability using a five-point hedonic scale (Muhimbula et al., 2011).

2.5. Statistical analysis

The effect of type of cereal, fermentation period and concentration of malt on physicochemical properties of the CFs flour and gruel were determined using a three-way analysis of variance (ANOVA). The validity of model assumptions, namely normal distribution and constant variance of error terms were verified for each response, by examining the residuals (Montgomery, 2013). ANOVA was used to see if there was a mean difference in response variables. When p values ($p < 0.05$) were found significant, Tukey's test was used for mean separation. Minitab®, Version 16 software was used for data analysis.

2.6. Ethics approval and consent to participate

The Ethical Review Board of Jimma University College of Agriculture and Veterinary Medicine has approved this study. It has been performed per the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments. Informed consent was obtained from each participant.

3. Results and discussion

3.1. Proximate composition

Table 1 presents proximate compositions of different cereal flours fermented for varying periods with added malt. Moisture, ash, crude protein, crude fat, fibre, carbohydrate and energy contents of the flours were significantly ($p < 0.05$) affected by cereal type, fermentation period and malt concentration.

3.1.1. Moisture content (MC)

The highest MC was recorded from 24h fermented flour with 2% added malt and the lowest was registered from 48h fermented flour with no added malt. The MC values recorded in this study were very close to the MC of CF flour made from fermented maize, rice, soybean and fish meal, which was reported in previous work (Amankwah et al., 2009). Variation in moisture content may not be explained as a function of fermentation or malt addition. The variation might have occurred due to

Table 1. Mean values for proximate compositions of flours of three different kinds of cereal treated with malt powder and fermented for varying periods.

Cereal type	Fermentation (h)	Malt (%)	Moisture	Ash	Protein	Fat	Fibre	Carbohydrate	Energy
Oats	0	0	5.0 ± 0.00^{efg}	1.8 ± 0.00^{ij}	11.1 ± 0.16^{j}	4.6 ± 0.07^{a}	4.6 ± 0.08^{de}	73.0 ± 0.19^{ijk}	377.3 ± 0.58^{bcd}
		2	5.0 ± 0.00^{efg}	1.8 ± 0.0^{1m}	11.4 ± 0.08^{ij}	4.4 ± 0.02^{a}	4.2 ± 0.04^{gh}	73.3 ± 0.13^{hij}	378.5 ± 0.21^{abc}
		5	5.0 ± 0.00^{efg}	1.8 ± 0.00^{kl}	11.8 ± 0.11^{hi}	4.1 ± 0.02^{b}	4.4 ± 0.14^{ef}	72.9 ± 0.04^{jk}	376.1 ± 0.65^{cdef}
	24	0	5.5 ± 0.00^{bcde}	1.8 ± 0.02^{ij}	12.6 ± 0.16^{ef}	3.6 ± 0.03^{c}	3.9 ± 0.03^{i}	72.5 ± 0.23^{jk}	373.3 ± 0.03^{fghi}
		2	6.2 ± 0.29^{a}	1.8 ± 0.01^{lm}	13.0 ± 0.05^{e}	3.3 ± 0.07^{f}	3.6 ± 0.05^{j}	72.3 ± 0.40^{kl}	370.4 ± 0.83^{j}
		5	5.2 ± 0.29^{def}	1.8 ± 0.01^{h}	13.7 ± 0.07^{d}	3.1 ± 0.06^{gh}	3.3 ± 0.03^{k}	73.0 ± 0.33^{jk}	374.1 ± 1.01^{efgh}
	48	0	4.7 ± 0.29^{fgh}	1.9 ± 0.01^{h}	14.4 ± 0.18^{c}	3.0 ± 0.03^{hi}	3.2 ± 0.07^{klm}	72.9 ± 0.31^{jk}	376.0 ± 1.43^{cdef}
		2	4.5 ± 0.00^{ghi}	1.9 ± 0.01^{h}	15.6 ± 0.31^{b}	2.9 ± 0.02^{ij}	3.1 ± 0.07^{lmn}	72.0 ± 0.28^{lm}	376.7 ± 0.32^{cde}
		5	4.5 ± 0.00^{ghi}	1.8 ± 0.02^{jk}	16.8 ± 0.11^{a}	2.7 ± 0.02^{kl}	3.0 ± 0.04^{mn}	71.2 ± 0.10^{m}	376.4 ± 0.08^{cde}
Barley	0	0	5.8 ± 0.29^{abc}	2.2 ± 0.00^{f}	8.8 ± 0.07^{pq}	3.3 ± 0.11^{ef}	6.0 ± 0.13^{a}	73.9 ± 0.30^{fgh}	360.6 ± 1.77^{mno}
		2	6.0 ± 0.00^{ab}	2.3 ± 0.01^{e}	9.0 ± 0.12^{p}	3.1 ± 0.04^{g}	5.8 ± 0.03^{ab}	73.8 ± 0.12^{ghi}	359.3 ± 0.36^{o}
		5	5.5 ± 0.00^{bcde}	2.1 ± 0.00^{g}	9.2 ± 0.13^{op}	2.9 ± 0.05^{hij}	5.6 ± 0.06^{b}	74.6 ± 0.21^{defg}	361.9 ± 0.28^{mno}
	24	0	5.0 ± 0.00^{efg}	2.2 ± 0.00^{f}	10.3 ± 0.16^{lm}	2.3 ± 0.06^{n}	4.8 ± 0.03^{c}	75.4 ± 0.20^{d}	363.2 ± 0.42^{lm}
		2	5.2 ± 0.29^{def}	2.30 ± 0.00^{e}	11.0 ± 0.15^{jk}	2.0 ± 0.07^{o}	4.8 ± 0.06^{cd}	74.7 ± 0.18^{def}	361.2 ± 1.07^{mno}
		5	5.5 ± 0.00^{bcde}	2.3 ± 0.00^{e}	11.8 ± 0.38^{hi}	2.0 ± 0.03^{op}	4.6 ± 0.03^{d}	73.9 ± 0.43^{fgh}	360.2 ± 0.12^{no}
	48	0	4.2 ± 0.29^{hij}	2.4 ± 0.00^{d}	12.4 ± 0.25^{fg}	1.9 ± 0.02^{pq}	4.4 ± 0.06^{fg}	74.8 ± 0.50^{de}	365.6 ± 1.46^{jkl}
		2	5.2 ± 0.29^{def}	2.2 ± 0.01^{f}	12.3 ± 0.09^{fg}	1.7 ± 0.03^{qr}	4.2 ± 0.02^{fg}	74.3 ± 0.34^{efg}	362.3 ± 1.29^{mn}
		5	4.0 ± 0.00^{ij}	2.3 ± 0.00^{e}	13.0 ± 0.21^{e}	1.6 ± 0.04^{r}	4.0 ± 0.02^{hi}	75.1 ± 0.19^{de}	367.1 ± 0.26^{k}
Teff	0	0	5.5 ± 0.00^{bcde}	2.7 ± 0.01^{b}	8.1 ± 0.11^{r}	3.5 ± 0.04^{cd}	3.2 ± 0.00^{k}	77.0 ± 0.15^{c}	372.2 ± 0.21^{hij}
		2	4.5 ± 0.00^{ghi}	2.6 ± 0.00^{c}	8.3 ± 0.10^{qr}	3.5 ± 0.02^{d}	2.9 ± 0.05^{no}	78.2 ± 0.11^{a}	377.2 ± 0.23^{bcd}
		5	5.2 ± 0.29^{def}	2.6 ± 0.00^{c}	9.5 ± 0.08^{no}	3.4 ± 0.03^{de}	2.7 ± 0.04^{o}	76.6 ± 0.43^{c}	375.1 ± 1.15^{defg}
	24	0	4.0 ± 0.00^{ij}	2.6 ± 0.00^{c}	9.9 ± 0.06^{mn}	2.8 ± 0.04^{jk}	2.5 ± 0.08^{p}	78.1 ± 0.14^{ab}	377.6 ± 0.27^{abcd}
		2	5.3 ± 0.29^{ghi}	2.7 ± 0.01^{b}	10.6 ± 0.08^{kl}	2.7 ± 0.02^{kl}	2.3 ± 0.09^{q}	76.4 ± 0.24^{c}	372.7 ± 1.30^{ghij}
		5	4.5 ± 0.00^{cde}	2.7 ± 0.00^{a}	11.7 ± 0.02^{hi}	2.7 ± 0.03^{l}	2.0 ± 0.08^{r}	76.5 ± 0.07^{c}	376.6 ± 0.45^{cde}
	48	0	3.8 ± 0.29^{j}	2.7 ± 0.00^{a}	11.8 ± 0.09^{hi}	2.6 ± 0.01^{lm}	1.9 ± 0.07^{rs}	77.2 ± 0.28^{c}	379.5 ± 1.42^{ab}
		2	3.7 ± 0.29^{j}	2.7 ± 0.01^{a}	12.1 ± 0.20^{gh}	2.5 ± 0.04^{m}	1.7 ± 0.05^{st}	77.3 ± 0.22^{bc}	380.3 ± 0.93^{a}
		5	5.7 ± 0.29^{abcd}	2.7 ± 0.01^{b}	12.6 ± 0.16^{ef}	2.2 ± 0.03^{n}	1.6 ± 0.02^{t}	75.3 ± 0.40^{d}	371.3 ± 1.06^{ij}
CV (%)			3.88	0.29	1.35	1.51	1.71	0.36	0.24

Notes: Unit for moisture, ash, protein, fat, fibre and carbohydrate content is g/100g and unit for energy content is Kcal/100g. Results are mean values of triplicate determination. Means with different letters across a column are significantly different.

differences in the water holding capacities of the flour components like carbohydrate and protein, which in turn were affected by the fermentation process and by the action of hydrolytic enzymes in the malt. Fermented cereal flours should have a moisture content of less than 10% (Olorunfemi et al., 2006).

3.1.2. Ash content

For the ash content, the highest value was recorded 48h fermented flour with no added malt whereas, the lowest was obtained from unfermented flour with 5% malt. The ash content of the CFs is within the recommended value ($\leq$3g/100g) for older infants and young children (FAO/WHO, 1991). Variations in the fermentation period and malt levels did not uniformly increase or decrease the total ash contents of the cereals. The observed difference in total ash content could be due to inherent variation in mineral contents of the cereals as well as leaching of some minerals into the fermentation medium during the decantation of the fermentation water. A study on cowpea fortified nixtamalized maize showed that fermentation medium and amylase-rich flour (ARF) level did not dramatically increase or decrease total ash content (Afoakwa et al., 2010). The total ash contents of all samples in the present study were less than 5% which was in agreement with the recommendation by WHO which advice that total ash contents of CFs should be less than 5g/100g (WHO & FAO, 2004).

3.1.3. Crude protein content

The highest crude protein content was recorded for 48h fermented flour with 5% added malt, and the lowest (8.12%) was obtained from unfermented flour with no added malt concentration. The protein content recorded for oats with 5% added malt and fermented for 48 h, falls within the recommended value range (>15g/100g) (FAO/WHO, 1991). Blending the cereals with pulses could significantly upgrade the protein content of the CFs. Protein content increased with an increase in the fermentation period and malt concentration. As both the fermentation period and malt concentration increased, the crude protein contents also increased for the three-grain types. This increment could be due to the degradation of complex proteins into peptides and amino acids by the proteolytic enzymes produced during fermentation (Nkhata et al., 2018). The increased protein content with increased malt concentration could be credited to the high proteolytic activities of the germinated seeds (Bello et al., 2020).

3.1.4. Crude fat content

Unfermented flour with no added malt had the highest crude fat content, while 48h fermented flour with 5% added malt had the lowest value. The crude fat content recorded in our study was lower than what is reported in a previous study by Amankwah et al. (2009), which may be attributed to varietal and composition differences. Prolongation in the fermentation period and the increase in malt concentration is associated with a gradual decrease in crude fat content. Other researchers have also reported that a more extended fermentation period decreased the crude fat content of fermented CFs. The reduction in fat content at the extended period of fermentation may have resulted from oxidation during fermentation. It could also be attributed to the use of lipid by the microorganisms to obtain energy for their metabolic activities during fermentation (Fasasi et al., 2007; Mbata et al., 2006). During germination of grains activities of lipolytic enzymes is increased, and fat component in the seeds is hydrolysed into fatty acids and glycerol (Bello et al., 2020). This hydrolysis explains the decrease in fat content with an increase in malt percentage.

3.1.5. Crude fibre content

Crude fibre content tends to lessen with a prolongation in the fermentation period and malt concentration and vice versa. This result is in agreement with a previous report by Igbabul et al. (2014) which justified the decrease could be owing to the activities of microorganisms which are known for the bio-conversion of carbohydrates and lignocelluloses into protein. CFs preferably have low fibre content to reduce the dietary bulk and hence indigestion in young children (Olorunfemi et al., 2006). Bulky nature of cereal-based CFs is one of the factors discouraging its consumption by infants and young children (Gernah et al., 2011). Therefore, the reduction in fibre content is desirable.

3.1.6. Carbohydrate content

Fermentation and addition of malt decreased carbohydrate content of the cereal-based CFs flours. The total carbohydrate content of unfermented flour does not increase or reduce consistently with the added malt. The total carbohydrate content decreased with the prolongation of the fermentation period and malt concentration, except for Teff flour. The decrease in carbohydrate content with an increase in malt percentage can be explained by the fact that the complex carbohydrates in grains are broken down into simpler and more absorbable sugars by the action of alpha-amylase, which are then utilized by the growing seedlings during germination (Bello et al., 2020). This change may also be due to the increasing or decreasing values of other chemical components like moisture, ash, protein, fat and fibre by the effect of malt and fermentation process. All the fermented flours in the current study contain the recommended amount of carbohydrate in the CFs of ≥65g/100g (WHO & FAO, 2004).

3.1.7. Energy content

CF flour sample with 0% added malt and fermented for 48h had the highest energy content. There was an inconsistent increase or decrease in energy content of the unfermented and 24-hour fermented flour samples with changes in the concentration of added malt. Prolongation in the fermentation period and an increase in malt concentration led to an increase in the calorific value for barley and Teff flours while resulted in a decrease for oats flour. This variation may be due to the increasing or declining values of the three sources of calories, namely protein, fat and carbohydrate by the effect of added malt and fermentation. The energy content obtained in the current study is less than the recommended energy content of 400–420kcal/100g for CFs for infants (WHO & FAO, 2004). The calorific contents were calculated for uncooked flour samples. Previous studies have shown cooking may further enhance the calorific content by changes in starch, fat and protein contents (Carmody et al., 2011).

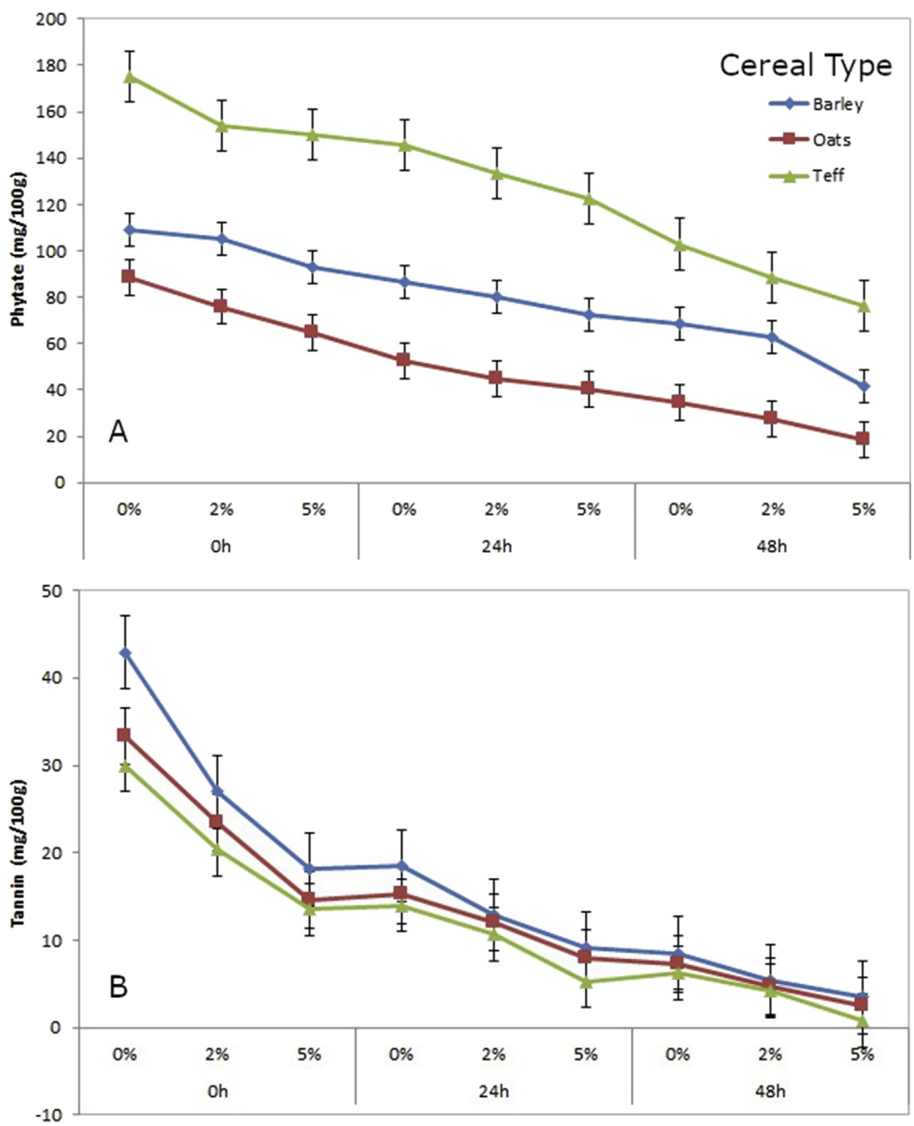

Figure 1. Anti-nutrition factors contents of different cereal flour fermented for varying periods and with added malt: (A) phytate and (B) tannin contents.

The energy content of the flour samples in this study ranges from 359.3-380.3 kcal/100g. Considering the mean energy content (369.8 kcal/100g) obtained in this study and comparing it with WHO's estimates of energy needs for non-breastfed children of 600 kcal/d at 6–8 months, 700 kcal/d at 9–11 months, and 900 kcal/d at 12–23 (World Health Organization, 2004), the kids should consume 162 g/d at 6–8 months, 189/d at 9–11 months, and 243 g/d at 12–23 months of age.

3.2. Antinutritional factors

Figure 1 presents phytate and tannin contents of the different cereal flours fermented for varying periods and with added malt. Phytate and condensed tannin contents were significantly ($p < 0.05$) affected by the type of cereal, fermentation period and concentration of added malt.

3.2.1. Phytate

Phytate content decreased consistently with the increase in the fermentation period and malt concentration where the lowest values were obtained for 48h fermented flours with 5% added malt. Our results are in agreement with another report, which showed that fermentation reduced phytic acid the most in the cereal flours compared to other processing techniques (Fagbemi et al., 2005). Fermentation can induce phytate hydrolysis to lower inositol phosphates via the action of microbial phytase enzymes. Different researchers have suggested that the loss of phytate during fermentation could be a result of the activity of native phytase and the fermentative microflora (Elyas et al., 2002; Shimelis and Rakshit, 2005).

3.2.2. Condensed tannin

Condensed tannin content decreased consistently with the increase in fermentation period and malt concentration where the lowest values were obtained for 48h fermented flours with 5% added malt. The activity of polyphenol oxidase produced by fermenting microflora might have caused a reduction in tannin contents as fermentation progress (Fagbemi et al., 2005).

The antinutritional factors such as the phytate and tannin content found in foods of plant origin are suggested to be a significant factor responsible for lowering the availability of minerals and some proteins. Therefore, fermentation is used in removing the complex matrixes between the antinutritional factors and the nutrients, thereby improving the bioavailability of nutrients in cereal-based CFs.

3.3. Functional properties

Figure 2 presents the functional properties of different cereal flours fermented for varying periods and with added malt. Bulk density, WAC and viscosity were significantly ($p < 0.05$) affected by cereal type, fermentation period and malt concentration.

3.3.1. Bulk density

The results showed that the bulk density of the cereal flours decreased consistently with a prolongation in the fermentation period and an increase in malt concentration. Previous studies have also reported that the bulk density of fermented cereals or cereal blends decreased as fermentation period increased (Alka et al., 2012). Bulk density depends on the combined effects of interrelated factors such as the intensity of attractive inter-particle forces, particle size, and the number of contact points (Elkhalifa and Bernhardt, 2010). The changes that occur at the molecular level during fermentation and the addition of malt could have resulted in a reduction of inter-particle attraction. The decrease in interparticle attraction distorts the relative rigidity of cells and gives the food a shrivelled appearance. As a result, on rehydration, the product may not readily absorb water and regain its initial firm texture as it was fresh material, thereby reducing the bulk density in gruel or porridge (Buta and Emire, 2015).

3.3.2. WAC

WAC of the cereal flours decreased steadily with an extension in the fermentation period and increase in malt concentration. This result is consistent with a report which stated that WAC of selected fermented cereal flours (sorghum, pearl millet and maize) decreased by half as fermentation period increased from 0 to 36 h (Alka et al., 2012). According to Afoakwa et al. (2010), the decrease in water absorption with increasing amylase rich flour (ARF) concentration is due to the breakdown of the starch by amylolytic enzymes (α-amylase and β-amylase) present in the ARF, which were suspected to be produced in the aleurone layer during the malting process.

3.3.3. Viscosity

The viscosity of gruel samples was significantly reduced with an extension in the length of fermentation and increment in the concentration of malt. A study on the addition of maize and millet malts to fermented maize showed that malt effectively lowered the viscosity of corn-based porridges (Amankwah et al., 2009). The decrease in viscosity during fermentation may be due to increased α-Amylase activity from the amylase-rich malt flour. This enzyme can hydrolyse amylose and amylopectin to low molecular weight carbohydrates such as dextrins and maltose, thereby reducing the viscosity of thick cereal porridges (Gibson et al., 2006). The hydrolysed starch granules during fermentation favour the reduction of starch swelling during cooking, which reduces the viscosity of the gruel or porridge (Buta and Emire, 2015). The viscosity of infant food must be less than 3000 cP (Mosha and Vicent, 2004). The viscosity values recorded in this study are far lower than 3000 cP which indicates the product is already liquified. There is no need to dilute these products with water to make them suitable for infant feeding as African mothers practice it.

3.4. Sensory properties

Table 2 presents the sensory scores of gruel samples made of different cereal flours fermented for varying periods and with added malt. Analysis of variance shows that there was a significant difference ($P < 0.05$) among the samples prepared from selected grain flours regarding appearance, aroma, taste, consistency and overall acceptability.

For all the three cereal types, the appearance of gruels prepared from 24h fermented and unfermented flour samples was the most preferred than 48h fermented flour. This preference is because gruels made from unfermented and 24h fermented flour were whitish while those made from 48h fermented flour were dark brown. The results obtained in this investigation were consistent with findings reported by Kikafunda et al. (2006), who stated that the most preferred porridge concerning appearance was the most white, while the least preferred was the creamiest in colour. The gruels prepared from 48h fermented flour was brownish. This browning is probably due to the formation of (melanoidins through a Maillard reaction when sugars from starch hydrolysis reacted with proteins, perhaps during oven drying following fermentation (Kikafunda et al., 2006).

The highest preference ranking for aroma was recorded for gruel made of 24h fermented oat flour with 5% added malt. Whereas gruel prepared from 48h fermented barley flour with 5% added malt was the least preferred regarding aroma. The production of volatile compounds such as lactic acid, butyric acid and alcohol by microbial activities which increased as the fermentation progressed may account for the perceived changes in the aroma of the gruels fermented for a different length of time (Oyewole and Ogundele, 2001). On the other hand, a more extended fermentation period led to lower taste preference score of gruel samples. This dislike could be due to higher acidity, which resulted from the prolonged fermentation time. This study is in agreement with Mihiret (2009) who reported that sensory panellists least accepted gruel prepared from 48h fermented sorghum flour.

Like the aroma, the highest preference ranking for taste was recorded for gruel made of 24h fermented oat flour with 5% added

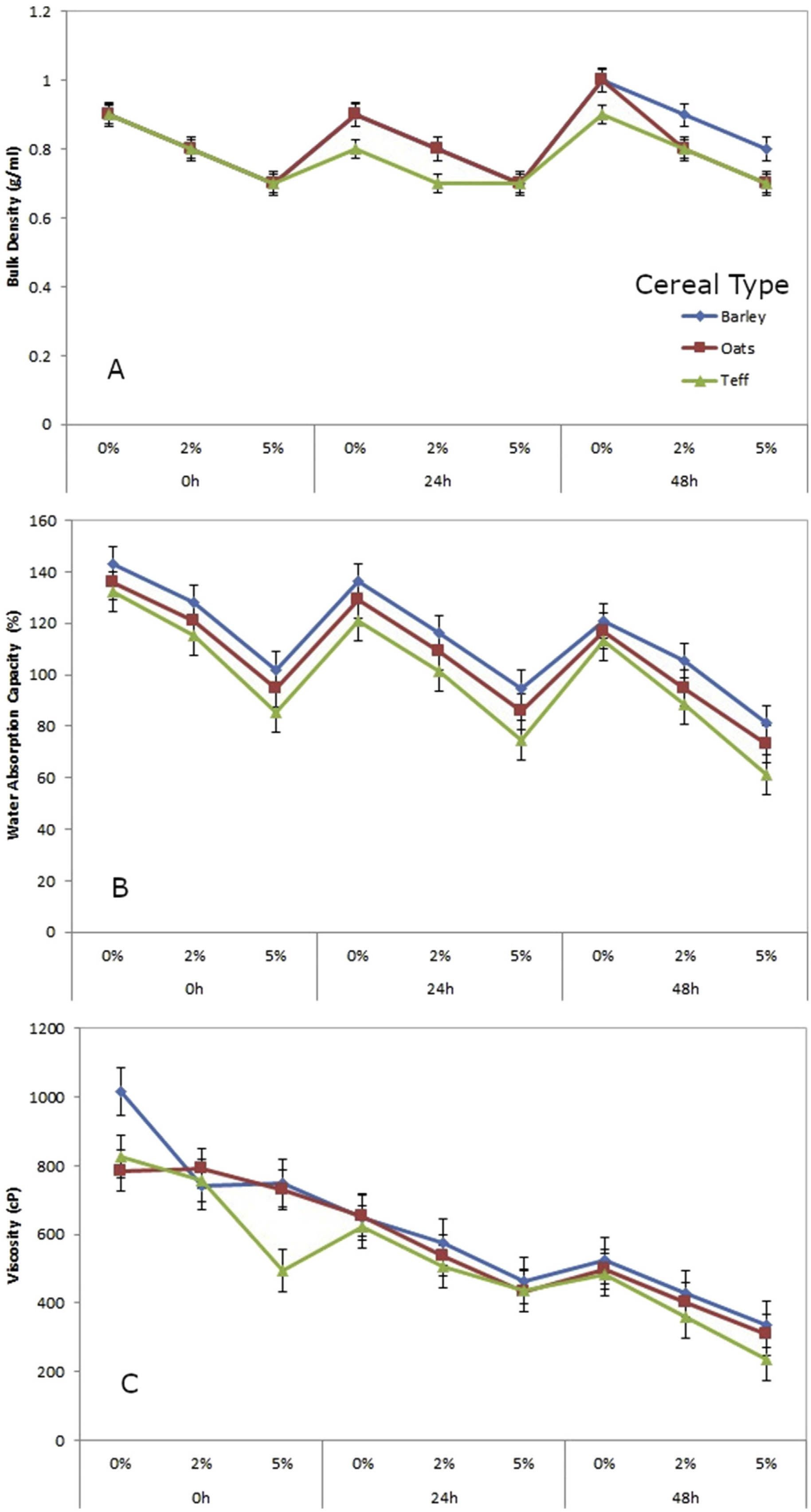

Figure 2. Functional properties of different cereal flour fermented for varying periods and with added malt: (A) bulk density, (B) water absorption capacity and (C) viscosity.

Table 2. Mean values for sensory scores of gruels made of oats, barley and teff flours with different concentration of added malt and fermented for varying periods.

Cereal type	Fermentation (h)	Malt (%)	Appearance	Aroma	Taste	Consistency	Overall acceptability
Oats	0	2	4.38^{a}	4.16^{ab}	4.02^{ab}	2.10^{b}	4.00^{ab}
	24	5	4.44^{a}	4.52^{a}	4.42^{a}	3.90^{a}	4.42^{a}
	48	2	2.14^{c}	2.28^{e}	2.38^{cd}	4.38^{a}	2.64^{d}
Barley	0	5	3.60^{b}	3.34^{cd}	3.48^{b}	1.64^{b}	3.28^{cd}
	24	0	4.06^{ab}	4.00^{ab}	3.72^{b}	3.76^{a}	3.80^{abc}
	48	5	1.88^{c}	2.20^{e}	1.94^{d}	4.02^{a}	2.66^{d}
Teff	0	2	3.90^{ab}	3.68^{bc}	3.58^{b}	2.26^{b}	3.40^{bc}
	24	0	3.90^{ab}	4.18^{ab}	4.06^{ab}	3.92^{a}	3.98^{ab}
	48	2	2.26^{c}	2.80^{de}	2.64^{c}	4.16^{a}	3.34^{bc}
CV (%)			29.43	29.25	32.86	34.05	31.08

Notes: Results are mean values of 50 rankings by untrained panellists on a 5 point hedonic scale. Means with different letters across a column are significantly different.

malt. Whereas gruel prepared from 48h fermented barley flour with 5% added malt was the least preferred regarding taste. The decrease in taste liking with extended fermentation could be due to higher acidity resulted from the prolonged fermentation time. This study agrees with the report of Mihiret (2009) who reported that sensory panellists least accepted gruels prepared from 48h fermented sorghum flour.

Similarly, the consistency of gruel prepared from both 24h and 48h fermented cereals were mostly preferred while gruel made from all unfermented cereal flours was least accepted. Gruels made from 24h, and 48h fermented flour was less thick (less viscosity) than unfermented cereals flours. The low viscosity might be due to the activity of fermentation microbes and amylase that convert starch to sugar and makes the gruels or porridge less thick. Starch degradation reduces the viscosity of thick cereal porridges while simultaneously enhancing their energy and nutrient densities (Michaelsen et al., 2009) and dilution of such CFs with water is not necessary.

The overall acceptability of gruel prepared from the starchy staples that were subjected to 24h fermentation was also ranked first. Short fermentation may lead to an improvement in palatability and acceptability by developing improved flavours and textures (Parveen and Hafiz, 2003).

Although in this work, the safety of the food product is not investigated, spontaneous fermentation which is performed regularly in the households is associated with wide micro-biodiversity. The presence of microbial pathogens and toxic by-products may be aspects liable to reduce the safety of the consumed product (Capozzi et al., 2017).

4. Conclusions

Results obtained showed that fermentation and addition of malt significantly affected the characteristics studied, notably the addition of 2% malt and 24h fermented sample. Fermentation and addition of malt resulted in a significant reduction in crude fat, crude fibre, total carbohydrate, phytic acid, tannin, bulk density and WAC. Fermentation and addition of malt have also caused a significant increment in crude protein and calorific value. Further, the gruel prepared from fermented cereals flour was less viscous and liquefied which, in turn will increase food intake by infants and young children. Fermentation and the addition of malt can play a significant role in improving the nutritional, functional and sensory properties of cereal-based CFs.

Declarations

Author contribution statement

Sirawdink F. Forsido: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Alemgena A. Hordofa: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Abebe Ayelign: Analyzed and interpreted the data; Wrote the paper.

Tefera Belachew: Conceived and designed the experiments; Analyzed and interpreted the data.

Oliver Hensel: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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