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ARTICLES

Effect of traditional and modified grain-soaking methods on physicochemical characteristics and consumers' acceptability of sorghum ogi	28
Bolade K. Mathew, Anota O. Adebawale and Bolade O. Oladayo	
Impact of the storage conditions and duration on some nutritional parameters of three flours of mass consumption in Cameroon	38
SONTSA-DONHOUNG Alain-Martial, BONGSE ANDOSEH Patience Kari, MABOUNE TETMOUN Abeline, BOUGNON Blaise and MOUNJOUENPOU Pauline	
Preparation and analysis of goat milk mozzarella cheese containing soluble fiber from Acacia senegal var. kerensis	46
Samuel N. Kiiru, Symon M. Mahungu and Mary Omwamba	
Food insecurity in the green famine belt of Ethiopia: Extent and severity in Belo-jiganfoy District, Benishangul-gumuz region	54
Guyu Ferede and Muluneh Wolde-Tsadik	

Full Length Research Paper

Effect of traditional and modified grain-soaking methods on physicochemical characteristics and consumers' acceptability of sorghum *ogi*

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The influence of traditional and modified soaking methods and varietal difference of sorghum [*Sorghum bicolor* (Linn.) Moench] grains on the physicochemical properties and consumers' acceptability of *ogi* was investigated. Three sorghum varieties (SAMSORG-14, SAMSORG-41 and SAMSORG-42) were used for the study, and each was subjected to three grain-soaking methods (SGW-72, PBW-24 and IBG5-24) after which *ogi* was produced and then oven-dried (55°C for 18 h). The pH of sorghum *ogi* prepared from IBG5-24 method was statistically higher ($p < 0.05$) than those from others while it exhibited a correspondingly lowest total titratable acidity. The water absorption capacity (252 to 293%) of *ogi* also varied with respect to the grain varieties and soaking methods applied. The pasting properties of *ogi* samples gave significantly varied values ($p < 0.05$) with respect to grain varieties and soaking methods, and these include peak viscosity (560 to 1311 cP), breakdown viscosity (117 to 317 cP), final viscosity (801 to 1571 cP) and setback viscosity (358 to 577 cP). The lightness index (L^* -value) of *ogi* from IBG5-24 method was statistically lower ($p < 0.05$) than that of others while both the swelling capacity and solubility index of *ogi* samples exhibited increasing values with the elevation of temperature of heating. The sensory quality rating of sorghum gruel (re-constituted and boiled *ogi*) revealed that *ogi* from 'SAMSORG-42 (PBW-24)' was rated the highest in terms of colour, taste, consistency, aroma and overall acceptability though not significantly different ($p < 0.05$) from samples of 'SAMSORG-14 (PBW-24)' and 'SAMSORG-41 (PBW-24)'. Grain-soaking methods and varietal difference have therefore been shown to influence the physicochemical characteristics and consumers' preference of sorghum *ogi*.

Key words: Sorghum, *ogi*, drying, physicochemical, soaking technique.

INTRODUCTION

Sorghum (*Sorghum bicolor* (Linn.) Moench) is a group member of small seeded cereal used for food or feed,

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and is sometimes called miscellaneous cereal or coarse grain (Kent and Evers, 1994). It has many cultivars widely grown sorghum grains is particularly important in the semi-arid tropics (SAT) where it provides appropriate calorie needs for the people in the region (Belton and Taylor, 2004). Sorghum cultivation has a special peculiarity with respect to its unique in Africa and Asia continents (Dicko et al., 2006). The ability to tolerate and survive under harsh climatic conditions of temporary logging, continuous or intermittent drought (Kent and Evers, 1994). Globally, sorghum grains have been observed of increasingly becoming a major food crop in Africa and India, and an important livestock feed in the developed countries (Felix et al., 2015). In many parts of Africa, sorghum grains plays an essential role in the attainment of food security for a lot of households while its commercial processing into value-added food and beverage products serves as income generating activities and an important driver for economic development (Taylor, 2004).

Several food products can be obtained from sorghum grains, particularly from Africa, and these include *ogi*, *kunu*, *eko* and *tuwo* (Obilana, 1982), malted and fermented beverages such as *mahewu* (Bvochora et al., 1999), porridge, *couscous* and *dolo* (Dicko et al., 2006), *injera*, *kisra* and *ugali* (Blandino et al., 2003), among others. *Ogi* is essentially a traditionally-extracted starch from maize, sorghum or millet through wet-milling of any of these cereal grains (Akingbala et al., 1987; Modu et al., 2005). It is this extracted starch called *ogi* that is converted to various other products such as *eko*, *agidi*, *akamu*, and *koko* depending on the locality and form in which it is consumed. When *ogi* is gelatinized into a stiff gel, it is called *eko* or *agidi* which is commonly consumed by adults with any of the local vegetable soups, '*moinmoin*' or '*akara*' (Oluwamukomi et al., 2005).

When gelatinized into gruel, it is called '*eko mimu*', *akamu*, or *koko* which is popular among infants as a weaning food and amongst adults as a breakfast meal and as a food for the convalescents (Teniola and Odunfa, 2001). The colour of *ogi* varies and depends on the type of cereal used for its production: white to yellow for maize, reddish-brown to gray for sorghum, and dirty-grey for millet (Onyekwere et al., 1989). The consumption of *ogi*-based food products cuts across different ethnic and economic classes along the West African coastal region where such products are given diverse local names (Teniola and Odunfa, 2001). Some of the problems associated with *ogi* production include limited shelf-life, inability to achieving a controlled fermentation with pure cultures and low nutritional quality (FAO, 1992).

A great number of research works had been carried out specifically on the production of *ogi* from sorghum grains. Akingbala et al. (1981) investigated the physical, chemical and sensory quality of *ogi* prepared from sorghum of differing kernel characteristics while the possibility of producing *ogi* from dry-milled sorghum

grains was evaluated by Adeyemi (1983). The enhancement of nutritional quality of sorghum '*ogi*' with leguminous protein sources was also investigated (Oyeleke et al., 1985; Nnam, 2001; Sanni et al., 2001; Adelekan and Oyewole, 2010; Akanbi et al., 2010; Makinde and Lapido, 2012; Ajanaku et al., 2012). Other research works include a comparative assessment of the nutritional quality of *ogi* prepared from three different cereal grains (sorghum, maize and millet) (Oyarekua and Eleyinmi, 2004), nutritional enhancement of sorghum *ogi* by using pawpaw for its fortification (Ajanaku et al., 2010), the effect of drying methods on selected properties of sorghum *ogi* (Esther et al., 2013), and dietary fortification of sorghum *ogi* using crayfish as supplements in infant feeding (Ajanaku et al., 2013).

One particular unit operation peculiar to the utilization of sorghum for most food production is the soaking of the grains. During soaking operation, grains are highly hydrated and the kernel softened to make grinding or cooking easier (Addo et al., 2006). Soaking can also cause the breakdown of several components, within the grains, into simpler compounds which are capable of causing alterations in the texture, flavour, aroma and taste of the final products (Parveen and Hafiz, 2003).

In West Africa, the traditional soaking method for cereal grains in the course of '*ogi*' production essentially involves soaking of the grains for up to 72 h at ambient temperature (25 to 35°C) after which the softened grains are wet-milled. However, a modification to the traditional grain soaking method was suggested by Nago et al. (1998) which involved initial mild boiling of the grains at 95 to 100°C for 10 min preceding soaking for 12 to 48 h at ambient temperature (25 to 35°C) followed by wet-milling. Some research works that are related to soaking of cereal grains during '*ogi*' production had also been reported.

Apotiola (2013) examined the effect of soaking period on '*ogi*' powder produced from sorghum while changes induced by soaking period on the physical properties of maize grains (Bolaji et al., 2014) and functional properties of maize '*ogi*' (Bolaji et al., 2017) were also investigated.

The present study, therefore, was aimed at examining the influence of varietal difference and grain soaking techniques, traditional and modified, on the physicochemical properties and acceptability of sorghum *ogi*; and this is the general objective of the work.

MATERIALS AND METHODS

Three varieties of sorghum (SAMSORG-14, SAMSORG-41 and SAMSORG-42) used in this study were obtained from the Institute of Agricultural Research (IAR), Samaru, Zaria, Nigeria.

Grain soaking procedures and '*ogi*' production

The soaking of sorghum grains was carried out using three different traditional methods:

Soaking of grains in tap water for 72 h at ambient temperature (SGW-72 method)

1 Kg of sorghum grains from respective variety was soaked in 10 L of tap water at ambient temperature ($29\pm 2^\circ\text{C}$). The soaking was done for a total period of 72 h during which the soaking water was being replaced at 12 hourly interval to slow down the fermentation process that could lead to over-souring. At the end of the soaking period, the water was drained off, the grains washed and wet-milled using a disc mill. The milled slurry was sieved using a fine mesh sieve to remove the over-tails which was discarded. The milky filtrate obtained was allowed to sediment for 18 h at ambient temperature ($29\pm 2^\circ\text{C}$) after which the souring water was decanted. The 'ogi' sediment was drained with the aid of muslin cloth and oven dried at 55°C for 18 h and sorghum 'ogi' powder obtained was stored.

Pouring of boiled tap water on the grains and allowing it to cool down for 24 h at ambient temperature (PBW-24 method)

10 L of boiled tap water (100°C) were poured onto 1 kg of sorghum grains of respective variety in a plastic bowl for the grains to be fully submerged. Both the soaking grains and the hot tap water were left in that position for 24 h during which they cooled down naturally to assume ambient temperature ($29\pm 2^\circ\text{C}$) after few hours. At the end of the steeping period, the water was drained off, the grains washed and wet-milled using a disc mill; while subsequent unit operations were similar to those carried out for 'SGW-72 Method' as explained earlier.

Initial boiling of sorghum grains for 5 min followed by cooling at ambient temperature for 24 h (IBG5-24 method)

10 L of tap water was initially brought to boiling in a stainless steel bowl to which 1 Kg of sorghum grains were added. Both were then allowed to boil for further 5 min after which they were brought down from cooking fire and then left in that position for 24 h during which they cooled down naturally to assume ambient temperature ($29\pm 2^\circ\text{C}$) after few hours. Thereafter, the subsequent unit operations carried out were similar to those done for 'SGW-72 Method' as explained.

pH determination of sorghum ogi

The pH of sorghum *ogi* was determined using a pH meter (model WPA CD70, India). After each determination, the pH probe was rinsed with distilled water and blotted dry (Sadler and Murphy, 2010). Triplicate determinations were made in all cases while the pH meter was calibrated using pH 4.0 and 9.0 buffers.

Determination of total titratable acidity of sorghum 'ogi'

The total titratable acidity (TTA) of sorghum *ogi* was determined by the method described by Sadler and Murphy (2010). 2 g of each sample were taken into a separate conical flask, and 20 ml of distilled water was added to each sample and shook properly on addition of an indicator (phenolphthalein). The mixture was further shaken properly and titrated against 0.1M NaOH, and the percentage acidity was expressed as lactic acid equivalent.

Evaluation of water absorption capacity of sorghum 'ogi'

The water absorption capacity (WAC) of sorghum *ogi* was evaluated by the method described by Sathe et al. (1982). 1 g of the sample was weighed into a tarred 20 ml centrifuge tube, and 10 ml of distilled water was added. The suspension was stirred for 5 min followed by centrifugation (Etek centrifuge, MP 400R, Electrocraft, India) at 3000 rpm for 30 min. The supernatant was decanted and the volume of water determined. The water absorbed by the dried sorghum *ogi* was calculated as the difference between the initial water used and the volume of supernatant obtained after centrifuging. The result was expressed as percentage of water absorbed by the dried sorghum *ogi*.

Determination of swelling power and solubility index of sorghum 'ogi'

The swelling power and solubility index of sorghum *ogi* were determined by using the method of Leach et al. (1959). Sorghum *ogi* (1 g, dry basis) was weighed into centrifuge tubes and 50 ml distilled water added. These tubes were immersed in a temperature-controlled water bath at temperature range of 50 to 90°C at 20°C interval for 30 min and thoroughly, and constantly stirred with glass rod during the heating period. The tubes were removed, cooled to room temperature and centrifuged (Etek centrifuge, MP 400R, Electrocraft, India) at 3,000 rpm for 15 min. The supernatant was carefully transferred into weighing petri dishes and evaporated over a steam bath and finally dried in an air oven at 105°C for 4 h. The weight of the dissolved solids was taken as a measure of solubility index of sorghum *ogi* samples. The sedimented slurry obtained after centrifugation was also weighed to get the weight of the swollen flour particles. The values were expressed as percentages of total swollen flour particles (swelling power) with respect to the original weight of the flour sample used.

Evaluation of pasting properties of sorghum 'ogi'

The pasting properties of sorghum *ogi* were evaluated using a Rapid Visco-Analyzer, RVA-Series 4, with the aid of a Thermocline for Windows, version 2.2 software (Newport- Scientific, 1998). A sample of 4.0 g sorghum *ogi* flour (14% moisture-basis) was transferred into a canister and approximately 25 ± 0.1 ml distilled water was added (correction factor was used to compensate for 14% moisture-basis). The slurry was heated to 50°C and stirred at 160 rpm for 10 s for thorough dispersion. The slurry was held at 50°C for up to 1 min followed by heating to 95°C over about 7.5 min and held at 95°C for 5 min, and finally cooled to 50°C over about 7.9 min. The parameters generated from the pasting curve include the peak viscosity, pasting temperature, time to peak, breakdown, holding strength or trough, setback, and final viscosity.

Determination of colour characteristics of sorghum 'ogi'

The colour of sorghum *ogi* samples was measured using a colour measuring instrument (ColorTec-PCM, model SN 3000421, USA) and the values expressed on the L^* , a^* , and b^* tristimulus scale. The L^* -value indicates lightness index while the positive a^* value indicates the red direction, negative a^* value is the green direction; positive b^* value is the yellow direction, and negative b^* value is the blue direction (Wojdylo et al., 2009). The instrument was first standardized ($L^*=93.24$, $a^*=0.96$, $b^*=-2.75$) with a business duplicating white paper (80 g/m^2). About 3 g of *ogi* sample was put

Table 1. pH, total titratable acidity and water absorption capacity of sorghum *ogi* obtained from different grain soaking methods¹.

Source of sorghum 'ogi'	pH	Total titratable acidity (TTA) (%)	Water absorption capacity (%)
SAMSORG-14 (SGW-72)	4.38±0.17 ^e	1.06±0.04 ^a	280±2 ^b
SAMSORG-14 (PBW-24)	4.46±0.06 ^e	0.81±0.03 ^c	282±2 ^b
SAMSORG-14 (IBG5-24)	4.65±0.11 ^d	0.75±0.05 ^{cd}	293±4 ^a
SAMSORG-41 (SGW-72)	4.66±0.12 ^d	1.07±0.07 ^b	258±2 ^{de}
SAMSORG-41 (PBW-24)	4.88±0.08 ^{bc}	0.82±0.06 ^c	261±2 ^d
SAMSORG-41 (IBG5-24)	5.02±0.07 ^{ab}	0.72±0.04 ^d	271±1 ^c
SAMSORG-42 (SGW-72)	4.84±0.05 ^c	1.02±0.05 ^a	252±3 ^f
SAMSORG-42 (PBW-24)	4.91±0.08 ^{abc}	0.83±0.03 ^c	255±2 ^{ef}
SAMSORG-42 (IBG5-24)	5.06±0.06 ^a	0.82±0.02 ^c	261±1 ^d

¹Results are mean values of triplicate determinations ± standard deviation. Mean values within the same column having the same letter are not significantly different at $p < 0.05$.

(SGW-72) = Method involving soaking of sorghum grains in tap water for 72 h at ambient temperature; (PBW-24) = Method involving pouring of boiled tap water on the sorghum grains and allowing it to cool down naturally for 24 h at ambient temperature; and (IBG5-24) = Method involving the initial boiling of sorghum grains for 5 min followed by natural cooling at ambient temperature for 24 h.

in a clean paper and the colour meter was placed on the sample by allowing the sensor to touch the sample. The reading was taken directly, and the results from three replicates per sample were averaged (McGuire, 1992).

Preparation of sorghum gruel (re-constituted and boiled *ogi*)

Sorghum gruel (re-constituted 'ogi') was prepared from each dried 'ogi' sample obtained from different soaking techniques. The gruel was prepared from dried 'ogi' (10.1 to 10.5%, moisture content) at overall ratio of dried 'ogi' to water of 1:10 (w/v). Cold slurry of the dried 'ogi' was first prepared by mixing 40% of the desired quantity of dried 'ogi' (100 g) with 40% of the desired quantity of water (1000 ml). This was followed by bringing 40% (400 ml) of the required quantity of water into boiling and the cold slurry initially prepared was added to this boiling water coupled with vigorous stirring, using a wooden flat spoon, to form a pap-like consistency. The remaining 20% of water (200 ml) was finally added to the pap-like consistency with vigorous stirring which was then allowed to cook for about 3 to 5 min after which it was ultimately stirred to ensure smoothness of the gruel. The final product so obtained is called sorghum gruel (re-constituted and boiled *ogi*).

Sensory evaluation of sorghum gruel (re-constituted and boiled *ogi*)

Sorghums gruel prepared from each of the dried sorghum 'ogi' from different varieties were evaluated for their sensory qualities and general acceptability. A scoring test was used which was designed to determine which of the products was most preferred. A 50-member semi-trained taste panel was requested to carry out the rating of gruel samples. The panelists were all familiar with the food product while they were also instructed on the use of sensory evaluation procedures. The sorghum gruel was presented to each panelist when its temperature was 38 to 42°C. Each of the panelists was asked to rate the samples on the basis of colour, taste, consistency, aroma and overall acceptability using a nine-point hedonic scale (that is, 9 = like extremely; 5 = neither like nor dislike; 1 = dislike extremely). The scores from the rating were subsequently subjected to analysis of variance (ANOVA), and the

means separated using Duncan Multiple Range test (IFT, 1981; Lawless and Heymann, 2010).

Statistical analysis

All determinations carried out were done in triplicates. A mean value and standard deviation were calculated in each case. ANOVA was also performed and separation of the mean values was by Duncan's Multiple Range Test at $p < 0.05$ using Statistical Package for Social Scientists (SPSS) software, version 16.0.

RESULTS AND DISCUSSION

Influence of grain soaking methods and variety on the pH, total titratable acidity and water absorption capacity of sorghum *ogi*

Table 1 presents the pH, TTA and WAC of dried sorghum 'ogi'. The pH of dried 'ogi' from SAMSORG-14 (4.38-4.65), SAMSORG-41 (4.66-5.02) and SAMSORG-42 (4.84-5.06) varied significantly ($p < 0.05$) with respect to the grains soaking methods adopted. The pH of 'ogi' from SGW-72 method was significantly the lowest which implies that the fermentation process during the soaking period was most severe. It had earlier been observed that during cereal grain soaking, a succession of naturally-occurring microorganisms would result in a population dominated by lactic acid bacteria (LAB) which are capable of producing organic acids with subsequent lowering of the pH of the fermenting material (Omemu, 2011).

The significance of pH of a food product is that it could determine the ability of microorganisms to grow in such product (Sadler and Murphy, 2010). Similarly, the pH of 'ogi' from IBG5-24 method was significantly ($p < 0.05$) the highest. The initial severe boiling of sorghum grains prior

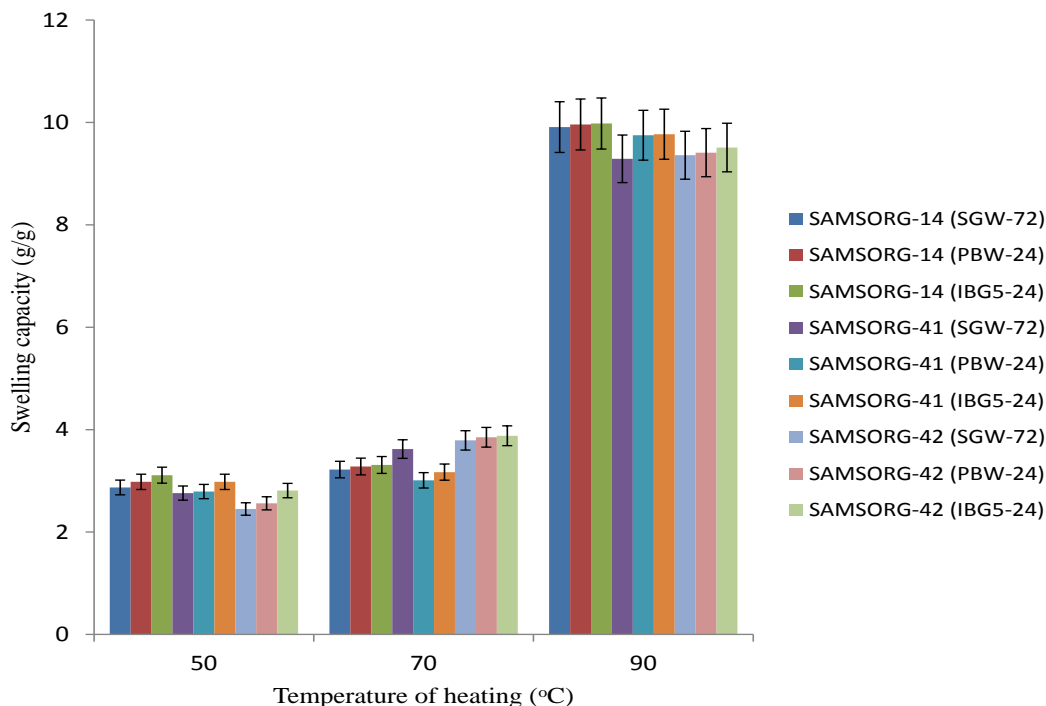


Figure 1. Swelling capacity of sorghum *ogi* obtained from different grain soaking methods. (SGW-72) = Method involving soaking of sorghum grains in tap water for 72 h at ambient temperature; (PBW-24) = Method involving pouring of boiled tap water on the sorghum grains and allowing it to cool down naturally for 24 h at ambient temperature; and (IBG5-24) = Method involving the initial boiling of sorghum grains for 5 min followed by natural cooling at ambient temperature for 24 h.

to soaking might be implicated to have caused a seeming delay in the fermentation process thereby leading to relatively high pH values. There were variations in the TTA of dried sorghum '*ogi*' obtained from SAMSORG-14 (0.75-1.06%), SAMSORG-41 (0.72-1.07%) and SAMSORG-42 (0.82-1.02%). The TTA of '*ogi*' from SGW-72 was observed to exhibit the highest value. This might also be attributed to a relatively intense fermentation process that gave rise to highest concentration of organic acids. The significance of TTA in a food product is connected with its ability to influence the flavour of such product (Sadler and Murphy, 2010).

The water absorption capacity (Table 1) of dried sorghum '*ogi*' produced from SAMSORG-14 (280–293%), SAMSORG-41 (258–271%) and SAMSORG-42 (252–261%) also exhibited variation with respect to the grain soaking methods applied. Sorghum '*ogi*' from IBG5-24 method was observed to have the highest water absorption capacity (WAC) while those from SGW-72 method exhibited the lowest values. The implication of these observations is that an intense fermentation process, as reflected in SGW-72 method due to its lowest pH values, might be responsible for such lowest WAC. Fermentation tends to decrease the capacity of the site for holding water in sorghum flour/starch (Elkhalifa et al., 2005). The significance of WAC of cereal-based flour/starch is that higher WAC suggests its usefulness in

the formulation of food product where a water holding attribute is an important consideration (Olayinka et al., 2008). However, lower WAC is desirable for making thinner gruels (Elkhalifa et al., 2005).

Swelling capacity and solubility of sorghum '*ogi*'

The swelling capacity of dried sorghum '*ogi*' obtained from different grain soaking methods is shown in Figure 1. There were variations in the swelling capacity of the samples at different temperatures of heating with a higher temperature giving greater swelling capacity values. At 50°C, the swelling capacities were SAMSORG-14 (2.87 to 3.11 g/g), SAMSORG-41 (2.76 to 2.98 g/g), and SAMSORG-42 (2.45 to 2.18 g/g); with respect to the grain soaking methods used. However at 90°C, the swelling capacities significantly increased ($p < 0.05$) which were SAMSORG-14 (9.91 to 9.98 g/g), SAMSORG-41 (9.29 to 9.77 g/g), and SAMSORG-42 (9.36 to 9.51 g/g). The higher swelling capacity of '*ogi*' samples at an elevated temperature could be attributed to the seeming weakening of the associative binding forces within the starch granules thereby causing a progressive hydration and subsequent swelling (Pal et al., 2002; Peroni et al., 2006). Figure 2 shows the solubility index of dried sorghum '*ogi*' samples obtained from different grain

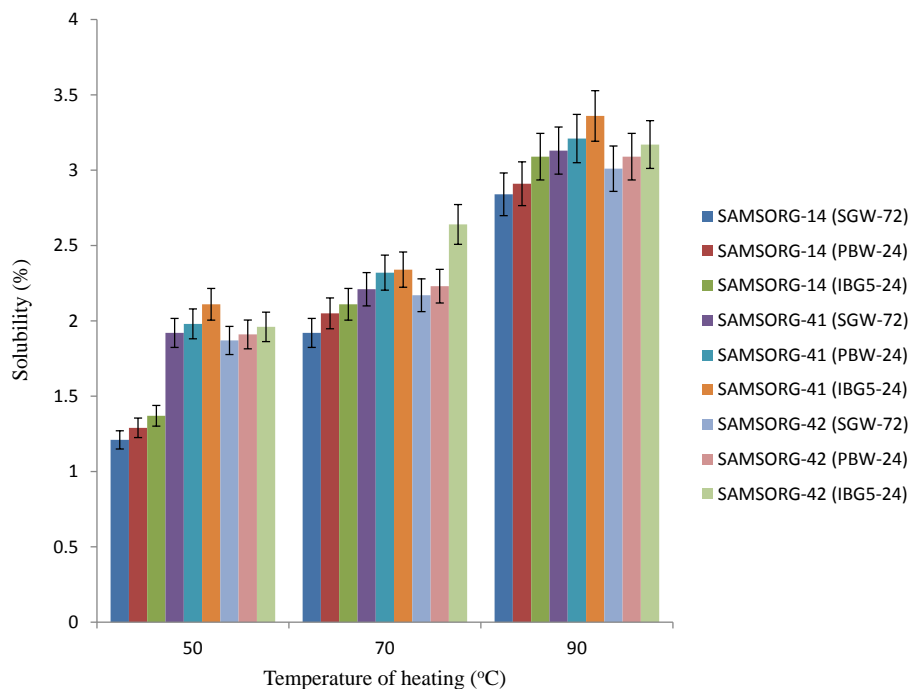


Figure 2. Solubility index of sorghum *ogi* as influenced by different grain soaking methods.

(SGW-72) = Method involving soaking of sorghum grains in tap water for 72 h at ambient temperature; (PBW-24) = Method involving pouring of boiled tap water on the sorghum grains and allowing it to cool down naturally for 24 h at ambient temperature; and (IBG5-24) = Method involving the initial boiling of sorghum grains for 5 min followed by natural cooling at ambient temperature for 24 h.

soaking methods. The solubility index was also observed to be dependent on temperature as higher temperature of heating led to greater solubility index. At 50°C, the solubility indices were SAMSORG-14 (1.21 to 1.37%), SAMSORG-41 (1.92 to 2.11%), and SAMSORG-42 (1.87 to 1.96%); with respect to the grain soaking methods applied. At higher temperature of 90°C, the solubility indices were higher and these include SAMSORG-14 (2.84 to 3.09%), SAMSORG-41 (3.13 to 3.36%), and SAMSORG-42 (3.01 to 3.17%). Sorghum 'ogi' from SAMSORG-41 seemed to exhibit greatest solubility index than other varieties. The higher solubility index at an elevated temperature had earlier been explained to be due to the weakening of intragranular binding forces within a starch molecule thereby causing the motional freedom of starch chains with subsequent increase in the solubility of the starch (Lawal, 2011).

Pasting properties of sorghum 'ogi' as influenced by varietal difference and grain soaking methods

Table 2 shows the pasting properties of oven-dried sorghum 'ogi'. The peak viscosity of SAMSORG-14 (560 to 942 cP), SAMSORG-41 (1043 to 1251 cP) and

SAMSORG-42 (1251 to 1311 cP) showed significant variations ($p < 0.05$) with respect to the grain soaking methods applied. Sorghum 'ogi' obtained from IBG5-24 method generally exhibited the lowest peak viscosity across the varieties which may be attributed to the severe boiling of the grains at the beginning of the soaking. The initial boiling might have caused partial gelatinization of the starch granules thereby leading to the formation of sorghum 'ogi' containing pre-gelatinized granules. The partially gelatinized starch granules seemed to have lowered the attainment of peak viscosity (Hidalgo et al., 2008; Pongjaruvat et al., 2014). The reduction in peak viscosity in 'ogi' from 'IBG5-24' method also indicated that the pre-gelatinized starch granules within the matrix caused retardation in the swelling of the granules during heating (Ragaei and Abdel-Aal, 2006). The breakdown viscosity of oven-dried sorghum 'ogi' from SAMSORG-14 (117 to 170 cP), SAMSORG-41 (189 to 342 cP) and SAMSORG-42 (295 to 317 cP) also exhibited significant variation ($p < 0.05$). Lower value of breakdown viscosity indicates increased paste stability during processing of the food product (Zaidul et al., 2007).

The final viscosity of 'ogi' from SAMSORG-14, SAMSORG-41 and SAMSORG-42 ranged from 801 to 1204, 1140 to 1561 and 1480 to 1571 cP, respectively.

Table 2. Pasting properties of sorghum *ogi* as influenced by different grain soaking methods.

Source of sorghum 'ogi'	Pasting factor ¹						
	Peak viscosity (cP) ²	Trough (cP)	Breakdown (cP)	Final viscosity (cP)	Setback (cP)	Pasting temp (°C)	Peak time (min)
SAMSORG-14 (SGW-72)	942±6 ^f	781±12 ^e	161±7 ^e	1204±18 ^d	423±13 ^d	87.7±0.1 ^d	7.0±0.2 ^a
SAMSORG-14 (PBW-24)	879±6 ^g	709±5 ^f	170±5 ^e	1105±15 ^f	396±7 ^e	93.5 ±0.1 ^b	7.0 ±0.1 ^a
SAMSORG-14 (IBG5-24)	560±5 ^h	443±10 ^g	117±9 ^f	801±11 ^g	358±9 ^f	94.8±0.2 ^a	5.7±0.1 ^c
SAMSORG-41 (SGW-72)	1251±10 ^c	1047±12 ^a	204±10 ^d	1561±19 ^a	514±14 ^b	87.6±0.1 ^d	5.4±0.1 ^d
SAMSORG-41 (PBW-24)	1207±14 ^d	1018±21 ^b	189±16 ^d	1510±18 ^b	492±17 ^c	92.8±0.1 ^c	6.5±0.2 ^b
SAMSORG-41 (IBG5-24)	1043±5 ^e	701±8 ^f	342±6 ^a	1140±15 ^e	439±9 ^d	94.9±0.2 ^a	5.2±0.1 ^d
SAMSORG-42 (SGW-72)	1311±7 ^a	994±8 ^c	317±8 ^b	1571±17 ^a	577±10 ^a	86.3±0.1 ^e	7.0±0.2 ^a
SAMSORG-42 (PBW-24)	1286±5 ^b	980±10 ^c	306±6 ^b	1506±17 ^{bc}	526±11 ^b	93.1±0.1 ^b	6.9±0.1 ^a
SAMSORG-42 (IBG5-24)	1251±7 ^d	956±10 ^d	295±7 ^c	1480±14 ^c	524±11 ^b	94.5±0.2 ^a	5.4±0.1 ^d

¹ Results are mean values of triplicate determinations ± standard deviation. Mean values within the same column having the same letter are not significantly different at $p < 0.05$. (SGW-72) = Method involving soaking of sorghum grains in tap water for 72 h at ambient temperature; (PBW-24) = Method involving pouring of boiled tap water on the sorghum grains and allowing it to cool down naturally for 24 h at ambient temperature; and (IBG5-24) = Method involving the initial boiling of sorghum grains for 5 min followed by natural cooling at ambient temperature for 24 h.

²cP = centipoise.

Lowest final viscosity was observed in sorghum 'ogi' from IBG5-24 method across the varieties. Final viscosity is essentially an index of the stability of cooked paste in actual use as a higher final viscosity value implies greater paste stability (Ragae and Abdel-Aal, 2006). The setback viscosity of sorghum 'ogi' varied significantly ($p < 0.05$) across the varieties which are SAMSORG-14 (358 to 423 cP), SAMSORG-41 (439 to 514 cP) and SAMSORG-42 (524 to 577 cP). The setback viscosity is usually used as an indicator of retrogradation tendency of the paste and the lower the value, the smaller the retrogradation tendency coupled with minimal syneresis (Sandhu et al., 2007).

Sorghum 'ogi' from all the varieties exhibited significant variations ($p < 0.05$) in their pasting temperature which are SAMSORG-14 (87.7 to 94.8°C), SAMSORG-41 (87.6 to 94.9°C) and SAMSORG-42 (86.3-94.5°C). Higher pasting temperatures were observed for sorghum 'ogi' from both PBW-24 and IBG5-24 methods. This may be attributed to the presence of partially-pregelatinized starch granules in these samples as a result of preliminary higher temperature of soaking. The pre-gelatinized granules seemed to serve as a resistant to gelatinization thereby causing the elevation of pasting temperature (Pongjaruvat et al., 2014). The variation in the pasting temperatures is basically an indication that sorghum 'ogi' samples exhibited different gelatinization temperatures (Newport-Scientific, 1998). The pasting temperature also serves as an indication of minimum temperature to cook a given sample with a concomitant implication for energy utilization (Ragae and Abdel-Aal, 2006).

The peak time for sorghum 'ogi' samples also varied in values which are SAMSORG-14 (5.7 to 7 min), SAMSORG-41 (5.2 to 6.5 min), SAMSORG-42 (5.4 to 7

min). Lowest peak time was generally observed for sorghum 'ogi' obtained from IBG5-24 method. The significance of peak time is that it serves as an index of the total time taken by each 'ogi' sample to attain its respective peak viscosity. Sorghum 'ogi' sample with a lower peak time would cook faster than that with a greater peak time.

Colour characteristics of sorghum 'ogi'

The colour characteristics of oven-dried sorghum 'ogi' prepared through different grain soaking methods are presented in Table 3. There were significant variations ($p < 0.05$) in the lightness index (L^* -value) of the samples and these are SAMSORG-14 (78.6 to 86.3), SAMSORG-41 (76.7 to 84.7) and SAMSORG-42 (79.7 to 83.7); with respect to the grain soaking methods used. Sorghum 'ogi' samples from IBG5-24 method were observed to exhibit the lowest L^* -value. This observation may be attributed to the soaking method used that involved an initial 5-minute boiling. This initial boiling of the sorghum grains might have caused a severe non-enzymatic browning within the endosperm of the grains thereby contributing to the lowering of the lightness index of 'ogi' produced from them. An earlier postulation by Horrobin et al. (2003) had stated that colour development in boiled/steamed cereal grains is essentially a resultant effect of interplay between moisture uptake by the grains undergoing such thermal application and gelatinization within the endosperm which could lead to a non-enzymatic browning reaction. The lowest L^* -value associated with IBG5-24 method also indicated that boiling of sorghum grains in the course of soaking had a high tendency of reducing the lightness index of product emanating from

Table 3. Colour characteristics of sorghum *ogi* as influenced by different grain soaking methods.

Source of sorghum 'ogi'	Colour variable ¹		
	L*	a*	b*
SAMSORG-14 (SGW-72)	86.3±2.1 ^a	8.1±0.8 ^a	13.2±1.1 ^a
SAMSORG-14 (PBW-24)	82.3±1.4 ^{abc}	5.4±0.5 ^b	12.5±1.1 ^{ab}
SAMSORG-14 (IBG5-24)	78.6±2.3 ^{cd}	4.1±0.4 ^{cd}	11.3±1.0 ^{abc}
SAMSORG-41 (SGW-72)	84.7±1.6 ^{ab}	7.9±0.2 ^a	12.8±1.9 ^{ab}
SAMSORG-41 (PBW-24)	81.2±2.8 ^{bc}	6.1±0.2 ^b	11.4±1.3 ^{abc}
SAMSORG-41 (IBG5-24)	76.7±2.0 ^d	3.5±0.3 ^d	10.4±0.8 ^{bc}
SAMSORG-42 (SGW-72)	83.7±2.8 ^{ab}	7.7±0.5 ^a	11.7±1.2 ^{abc}
SAMSORG-42 (PBW-24)	82.4±1.9 ^{abc}	5.5±0.3 ^b	10.7±1.4 ^{bc}
SAMSORG-42 (IBG5-24)	79.7±1.7 ^{cd}	4.4±0.2 ^c	10.1±0.9 ^c

¹ Results are mean values of triplicate determinations ± standard deviation. Mean values within the same column having the same letter are not significantly different at $p < 0.05$. (SGW-72) = Method involving soaking of sorghum grains in tap water for 72 h at ambient temperature; (PBW-24) = Method involving pouring of boiled tap water on the sorghum grains and allowing it to cool down naturally for 24 h at ambient temperature; and (IBG5-24) = Method involving the initial boiling of sorghum grains for 5 min followed by natural cooling at ambient temperature for 24 h.

Table 4. Sensory quality rating of re-constituted sorghum *ogi* produced from different grain soaking techniques.

Re-constituted sorghum 'ogi' sample	Sensory factor ¹				
	Colour	Taste	Consistency	Aroma	Overall acceptability
SAMSORG-14 (SGW-72)	7.8 ^b	6.4 ^c	6.1 ^f	6.5 ^c	6.6 ^d
SAMSORG-14 (PBW-24)	8.1 ^a	8.0 ^a	7.8 ^a	7.9 ^a	8.1 ^b
SAMSORG-14 (IBG5-24)	7.3 ^c	8.1 ^a	7.4 ^b	7.1 ^b	7.5 ^c
SAMSORG-41 (SGW-72)	7.9 ^{ab}	6.6 ^c	6.4 ^e	6.5 ^c	6.5 ^d
SAMSORG-41 (PBW-24)	8.2 ^a	8.1 ^a	7.9 ^a	8.0 ^a	8.1 ^b
SAMSORG-41 (IBG5-24)	7.4 ^c	7.8 ^{ab}	7.2 ^{bc}	7.1 ^b	7.6 ^c
SAMSORG-42 (SGW-72)	7.8 ^b	6.5 ^c	6.8 ^d	6.6 ^c	6.7 ^d
SAMSORG-42 (PBW-24)	8.2 ^a	8.1 ^a	8.0 ^a	8.2 ^a	8.4 ^a
SAMSORG-42 (IBG5-24)	7.2 ^c	7.7 ^b	7.6 ^b	7.3 ^b	7.7 ^c

¹ Results are mean values from 50 panelists. Mean value within the same column having the same letter are not significantly different at $p < 0.05$. The sensory quality rating was carried out using a nine-point hedonic scale (i.e. 9 = like extremely; 5 = neither like nor dislike; 1 = dislike extremely). (SGW-72) = Method involving soaking of sorghum grains in tap water for 72 h at ambient temperature; (PBW-24) = Method involving pouring of boiled tap water on the sorghum grains and allowing it to cool down naturally for 24 h at ambient temperature; and (IBG5-24) = Method involving the initial boiling of sorghum grains for 5 min followed by natural cooling at ambient temperature for 24 h.

the grains. The '±a-value' is essentially a measure of the degree of redness and greenness while '±b-value' stands for the degree of yellowness or blueness in a material (Giese, 2000). These two factors, however, may not be useful indices for explaining the colour characteristics of sorghum 'ogi' in this study as grain colour of the varieties is somewhat gray. These factors are popular in the visual colour evaluation in fruit ripening (Ferrer et al., 2005).

Organoleptic quality of sorghum gruel (re-constituted and boiled *ogi*) as influenced by grain soaking methods and varieties

The sensory quality rating of re-constituted sorghum 'ogi'

is presented in Table 4. It was observed that sorghum gruel prepared from 'SAMSORG-42 (PBW-24)' was rated the highest in terms of colour, taste, consistency, aroma and overall acceptability. The rating, however, was not significantly different ($p < 0.05$) from 'SAMSORG-14 (PBW-24)' and 'SAMSORG-41 (PBW-24)'. The quality assessment revealed that the products with the highest sensory rating were all from 'PBW-24' soaking technique. The implication of this is that the consumers seemed to prefer sorghum gruel emanating from the grain soaking technique that involved the initial pouring of hot water on the grains and allowing it to cool down naturally for 24 h at ambient temperature. Another inference from this quality assessment is that sorghum gruel from 'SGW-72' soaking technique was significantly ($p < 0.05$) rated the

lowest. Variations in the grain soaking methods and sorghum varieties had shown to influence consumers' preferences.

Conclusion

It could be drawn from this study that grain soaking techniques as well as varietal difference of sorghum grains did have a great influence on the ultimate properties of sorghum 'ogi' derived from the kernel. These include variations in the pH, total titrable acidity and water absorption capacity. Other parameters that were influenced were the pasting properties, swelling capacity, solubility index and colour characteristics of 'ogi' samples. The sensory quality rating of sorghum gruel (re-constituted 'ogi') revealed that the most preferred product came from 'PBW-24 soaking technique' which is a method involving pouring of boiled tap water on the sorghum grains and allowing it to cool down naturally for 24 h at ambient temperature. The practical relevance of these findings is that the desired physicochemical characteristics and consumers' acceptability of sorghum 'ogi' could be influenced by both the grain soaking methods and variety.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Impact of the storage conditions and duration on some nutritional parameters of three flours of mass consumption in Cameroon

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Wheat, maize and cassava flours are of mass consumption in Cameroonian households. Depending on the frequency of consumption and the size of households, these flours can take several months before complete exhaustion. The present work assessed the impact of three common storage conditions (aerobic, partial aerobic and anaerobic) on the evolution of some nutritional parameters of these flours. The results showed that nutritional parameters varied with conditions of storage and duration. Crude protein was the most affected parameter. After a month of storage, more than 90% of crude protein content dropped irrespective of storage condition and type of flour. Carbohydrate content increased after a month of storage and decreased during the second month. On the other hand, total lipid and ash content did not varied. Generally, nutritional parameters deteriorated more in aerobic condition, followed by partial anaerobic and then total anaerobic condition. Ultimately, total anaerobic environment was recommended for better conservation of flours.

Key words: Flour, mass consumption, storage conditions, nutritional evaluation.

INTRODUCTION

Cereals (corn, wheat and rice) remain the main staples in Sub saharan African (36.2% caloric intake and 40% protein intake), followed by roots, tubers and starchy foods. According to the 'Document of Development Strategy of Rural Area (DSDSR, 2005) report of the

Cameroonian Ministry of Agriculture and Rural Development, cereals, fruits, vegetables, and tubers represent 50% of the total food demand, while animal production contribute for only 23 %.

However these grains (rice and wheat) which are

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imported represent 56% of the total budget spent by urban households in contrast to those produce locally (maize, millet, sorghum), which represent 37% of the total budget (Dury et al., 2000). Cereals are usually processed into flour and are used in baked products. FAO,1990) They are also the basis of several dishes like fufu, pasta and cakes. Cereals can also be eaten in the form of semolina and broken grains (Khaly, 1998). Depending on the size of the household and the frequency of consumption, these flours can spend several months before being completely eaten. The conditions of storage are a critical factor in determining the storage stability of cereal products. (Cell of the NGO Green Africa, 2003).The humid tropical climate of some African regions is a critical factor for the preservation of these products. In this type of atmospheric humidity conditions, preservation of flour is a main constraint.

The general objective of this study was to study the impact of the storage conditions on some nutritional parameters of three flours of mass consumption (maize, wheat, cassava). More specifically, this study was to determine some physico-chemical parameters (moisture, ash, protein, carbohydrate, lipid contents) of these flours under three different storage conditions.

MATERIALS AND METHODS

Traditional production of cereal flours

Corn and cassava flours were processed locally at the Laboratory of Food Technology of the Institute of Agricultural Research for Development (IRAD) Cameroon while the wheat flour was procured from a local market in the city of Yaoundé:

1. *Wheat flour (Triticum aestivum)* being an imported commodity was bought at a local market in the city of Yaoundé.
2. *Corn flour*: Yellow corn (*Zea mays*) was crushed and ground into flour with a hammer mill. The resulting powder was sieved to separate chaff from flour.
3. *Cassava flour*: Cassava tubers (*Manihot esculenta*) were washed in clean water, then peeled and sliced into chips. The strips were dried under the sun for 3 days. These chips were later milled with a hammer mill. The cassava flour obtained was sieved in order to eliminate impurity.

Experimental set up

Three conditions of flour storage was studied:

1. Storage in aerobic conditions where samples were kept in a completely open container and exposed to ambient environment (about 25°C);
 2. Storage in partial anaerobic conditions where samples were kept in a semi-open container at room temperature.
 3. Storage in anaerobic conditions where flour samples were kept in a container hermetically closed, at room temperature.
- Flours were kept for 60 days and every 4 weeks, samples of each treatment were analysed.

Physico-chemical analysis

The studied parameters were: Moisture content, ash, crude protein, total lipid content, and carbohydrate content.

1. The moisture content was carried out according to the standard ISO NF ISO 11465: 1994 X31-102. Five grams of each sample was heated in an oven at 103°C for 4 h. Samples were then cooled in a desiccator. The lost in weight was calculated as percent moisture.

$$\text{Moisture H (\%)} = (P - P1) \times 100 + 0.3 / P1$$

Where P = the test and P1 = weight of dry residue intake dry.

2. Ash content: 5 g of each flour sample underwent oxidation combustion in an oven at 550°C for 24 to 48 h. The mineral residue remaining was calculated as the ash percentage.
3. Crude protein: The crude protein was determined using the KJELDAHL method (AFNOR, 1991). Samples were mineralized by concentrated sulphuric acid in the presence of a catalyst, followed by an alkalization of the reaction products (ammonium sulphate) with soda concentrated laundry.
4. Total lipid content was determined by the soxhlet extraction method as described by Bourelly (1982). Fat was extracted from 5 g of flour samples in 300 ml at about 50°C. After 3 h of extraction, the extracted fat was dried at 95°C for 1 h.
5. Total carbohydrate content was determined using an indirect method as described by Noor et al. (2012). This method consisted of subtracting the sum of moisture, ash, protein, lipid percentage from a hundred.

$$\text{Total carbohydrate} = 100 - [\text{ash (\%)} + \text{protein (\%)} + \text{fat (\%)} + \text{moisture (100\%)}].$$

Statistical analysis

The results were analysed using the statistical software R.3.1.2. Normality tests (Kolmogorov Smirnov) were first made to assess storage conditions on the physicochemical parameters of different types of flours. For normally distributed data, the analysis of variance (ANOVA) three factors allowed to study the influence of the type of flour, the storage duration and storage condition on the various nutritional parameters. However for abnormally distributed data, the kruskal-Wallis test was used to measure the influence of different factors among themselves. At the end of these tests, the boxplots was done to illustrate these various measured parameters.

RESULTS AND DISCUSSION

Effect of storage conditions and duration on some physico- chemical parameters

The macromolecules of the flours (lipid, protein and carbohydrate), as well as the moisture and ash content varied from one flour sample to another, and also within the same flour, depending on the storage condition and duration. These various variations are presented in Tables 1 to 3.

Effect on moisture content

The effect of the storage conditions and duration on the

Table 1. Evaluation of some nutritional parameters of wheat flour with storage conditions and duration.

Storage condition	Storage duration (days)	Moisture content (%)	Lipids (%)	Protéin (%)	Ash (%)	Carbo-hydrate (%)
Aerobic	0	15.304	1.84	1.257	0.700	80.898
	30	14.505	1.756	0.160	0.800	82.778
	60	12.610	1.200	0.086	0.600	82.404
Partial anaerobic	0	15.304	1.840	1.257	0.700	80.898
	30	14.155	1.761	0.079	0.700	82.304
	60	13.760	1.400	0.051	0.700	81.809
Total anaerobic	0	15.304	1.840	1.257	0.700	80.898
	30	13.970	1.787	0.159	0.800	83.283
	60	13.631	1.801	0.064	0.700	80.706

Table 2. Evaluation of some nutritional parameters of corn flour with storage conditions and duration.

Storage condition	Storage duration (days)	Moisture content (%)	Lipid (%)	Protéin (%)	Ash (%)	carbohydrate (%)
Aerobic	0	11.970	3.500	1.725	2.000	80.804
	30	13.070	3.340	0.110	1.800	81.679
	60	11.975	3.600	0.101	1.700	79.838
Partial anaerobic	0	11.970	3.500	1.725	2.00	80.804
	30	11.851	3.320	0.116	1.800	82.913
	60	12.740	3.200	0.055	1.900	79.205
Total anaerobic	0	11.970	3.500	1.725	2.000	80.804
	30	12.301	3.160	0.110	1.900	82.529
	60	11.850	3.600	0.115	1.900	80.992

Table 3. Evaluation of some nutritional parameters of cassava flour with storage conditions and duration.

Storage condition	Storage Duration (days)	Moisture content (%)	Lipids (%)	Protéin (%)	Ash (%)	carbohydrate (%)
Aerobic	0	14.505	1.820	1.486	3.100	79.089
	30	12.930	1.770	0.000	2.900	81.41
	60	13.245	1.400	0.028	3.100	80.422
Partial anaerobic	0	14.505	1.820	1.486	3.100	79.089
	30	14.301	1.730	0.000	3.100	80.87
	60	13.760	1.200	0.000	3.400	79.718
Total anaerobic	0	14.505	1.820	1.486	3.100	79.089
	30	14.170	1.800	0.000	3.200	80.83
	60	14.015	1.600	0.000	3.000	79.764

moisture content depended on the type of flour: after 60 days of storage, the moisture content of wheat flour decreased from 15.3% (T_0) to 12.6% in aerobic conditions,

from 15.3% (T_0) to 13.7% in partial anaerobic conditions, and from 15.3 to 13.6% in total anaerobic conditions. As for cassava flour, moisture content decreased from 14.5 -

13.2%, 14.5-13.7%, and 14.5-14.0%, respectively in aerobic, partial anaerobic and total anaerobic conditions. Concerning corn flour, the moisture content did not significantly vary in aerobic conditions (about 11.9%). In partial anaerobic conditions, moisture content varied from 11.9 to 12.7%, and from 11.9 to 11.8% in total anaerobic conditions.

Effect on ash content

The initial ash contents were 0.7, 2 and 3% respectively for wheat flour, corn and cassava. Irrespective of the storage conditions (aerobic, partial anaerobic and total anaerobic) and duration, the values remained almost constant with no significant variation.

Effect on crude protein content

Crude protein varied considerably regardless of the storage duration. After 30 days of storage, total protein content dropped irrespective of the storage condition, more than 90% of total protein was lost during the first month of storage. Crude protein in corn flour varied from 1.7 to 0.1%, irrespective of the storage condition. In cassava flour, crude protein was not more detectable after two months as it varied from 1.5% to undetectable irrespective of the storage condition. Crude protein in wheat flour varied from 1.3 to 0.1%, irrespective of the storage condition.

Effect on total lipid content

Lipid content of corn flour was relative constant regardless of the storage condition and duration. It varied from 3.5 to 3.6, 3.5 - 3.2 and 3.5 - 3.6% respectively in aerobic, partial anaerobic and total anaerobic conditions. Variation in cassava flour was more significant than in corn flour with values varying from 1.8 - 1.4, 1.8 - 1.2 and 1.8 - 1.6% respectively in aerobic, partial anaerobic and total anaerobic conditions. The same trend was observed in wheat flour with values varying from 1.8 - 1.2, 1.8 - 1.4 and 1.8 - 1.8% respectively in aerobic, partial anaerobic and total anaerobic conditions.

Effect on carbohydrate content

The carbohydrate content in wheat, maize and cassava flour underwent a very slight variation during storage (aerobic, partial anaerobic or total anaerobic) with the mean carbohydrate content fixed at 81%. There was a slight increase of the sugar content after 30 days of storage, followed by a slight decline after 60 days.

Most of grains and oilseeds productions in wet tropical climate and especially in wet African regions are simply

lost, or else sees their nutritional and health characteristics deteriorate because of poor storage conditions. Some physico-chemical parameters of corn, cassava and wheat flours were followed during 60 days of storage under 3 conditions of storage: Aerobic, partial anaerobic and total anaerobic. The results had showed that nutritional parameters were much more deteriorated in aerobic condition, followed by partial anaerobic and total anaerobic conditions.

Low moisture content in flour is essential during storage because it favours shelf life stability of flour (Eleazu et al., 2012). Higher moisture content has been reported to accelerate or enhance microbial growth (Aryee et al., 2006, Souci et al. 1994) by hydrolysis of starch through their amylases and thereby facilitate acidification of flour. Chene (2001) stated that moisture content of flour for a good storage must be range between 10 and 13%. This was in conformity with our results as the values obtained (11 to 14%), fell within the range. Thus, according to Amarachi et al. (2015) humidity criteria, the flours used in this study had the potential of good storage quality.

Knowledge of the ash content in flours is essential because it not only gives a quantitative estimates of the minerals available (Eleazu et al., 2012), but also allows the milling industries to estimate the expected flour yield as well as identify the milling functionality of flour. The ash content is a measure of the purity of the flour. It defines commercial types of flours (Feillet, 2000). The results obtained showed that only wheat flour samples were in conformity with the standard (inferior to 1%) as stated by Codex Alimentarius. Therefore, independently to storage condition, corn and cassava flour had ash content largely above the standard.

Crude protein content in corn flour was very low, tending to zero after just one month of storage. This results was far below the normal value (7%) as recommended by FAO,1996. It could be attributed to the high husking of corn grains which favours elimination of protein contained in the pericarp of the grain. Amarachi et al. (2015) reported that cassava tubers are generally low in protein, with cassava flour having 1.5% content. Cassava flour samples had initial crude content which are conform to the recommandation, but after 30 days of storage, these value dropped and become undetectable. Crude protein in wheat flour was lower than the value given by Godon and Michelle (1998),Grandvoinet and Pratz (1994) for whom the normal value destined for manufacturing cooking products must be range between 7 and 15%.

Samples of maize flour presented a total fat values ranging from 3.2 to 3.6%, which is less than the value determined by the codex Alimentarius (4.5%). The process of obtaining flour from local products seem not to have a significant impact on the lipid content of corn flour. According to Khally (1998), total fat content of cassava

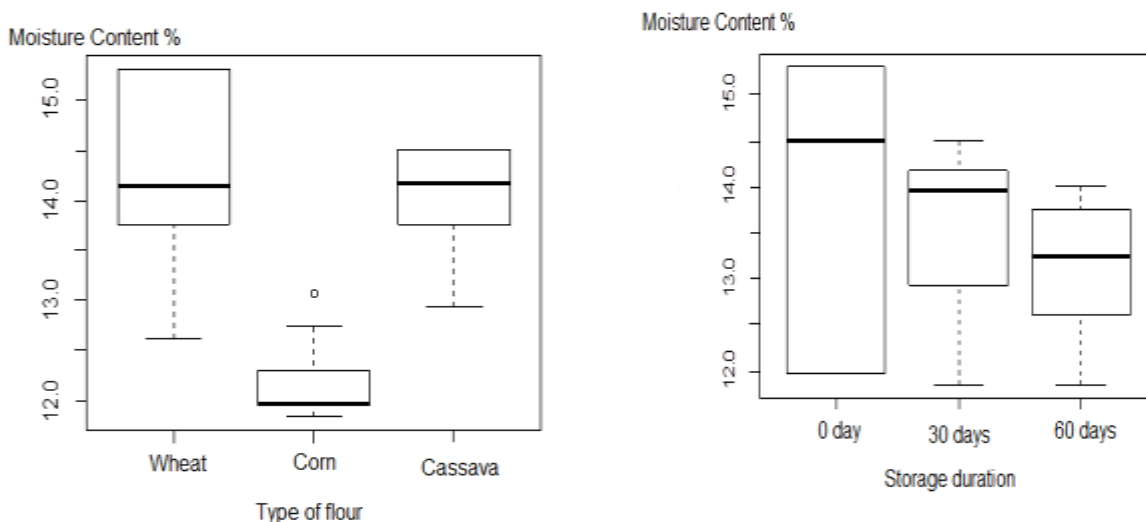


Figure 1. Moisture content based on: (a) The type of flour; (b) The storage duration.

flour is 1.5%. In this study, certain samples had total fat content superior to this threshold value, drawing attention to the need for good storage. If not, lipolysis of free fatty acids could occur and could impairing alteration in short-term period (Finney et al., 1950). For Feillet (2009), wheat flour have lipid content of 1.4 to 2%. This results was in conformity with the studied wheat flours.

The test of normality of datas from studied parameters

The test of normality on moisture, carbohydrate, total lipid, crude protein, and ash datas revealed that only moisture and carbohydrate data were normally distributed (p-value inferior to 0.05).

Analysis of variance on the normally distributed data

Three way ANOVA for moisture content of flour: The ANOVA three factors was carried out on the moisture content of flours. Significant p-values were obtained with the parameters: Type of flour, duration of storage and the interaction of both parameters (type of flour/duration of storage). These results demonstrated the influence of these 3 settings on the moisture content of flours.

Figure 1a and b illustrates these influences. Figure 1a revealed that wheat and cassava flour moisture content were significantly higher than that of corn. This could be explained firstly by the water added to the wheat before milling and secondly by water content of the cassava tuber. Similarly, Figure 1b below revealed that the moisture content of flours decreased with the increase of

the storage time. This could be due to the use of water molecules included in flours for the hydrolysis of constituents. In fact, a high water content promotes the proliferation of microorganisms capable of using their amylases to hydrolyze the starch present in the flour over time. This decrease is more pronounced for the storage in total anaerobic than aerobic. This confirms that the anaerobic was more favourable to good preservation of the flours.

ANOVA three factors in the carbohydrate content of flours: Significant p-values ($p < 0.05$) were obtained with the type of flour and storage duration. This respectively revealed the influence of the type of flour and duration of storage on the carbohydrate content of flours.

Figure 2a and b below illustrates these results. Figure 2a showed that carbohydrate content was significantly higher in the wheat and corn flours, than in that of cassava. Similarly, Figure 2b showed that carbohydrate content in the flour increased after a 30 days of storage, then decreased after 60 days. This increase would be due to the release of reducing sugars by hydrolysis of starch content in the different flours (Collard and Lev, 1959) then the decrease in time T2 will be the effect of the use of these sugars for fermentation. Indeed the simple sugars are quickly used by the yeast during the fermentation (Grandvoinet and Pratz, 1994).

Ranking Kruskal-Wallis test on non - normally distributed data

The test of Kruskal-wallis ranking was achieved on the physicochemical parameters not complying with the

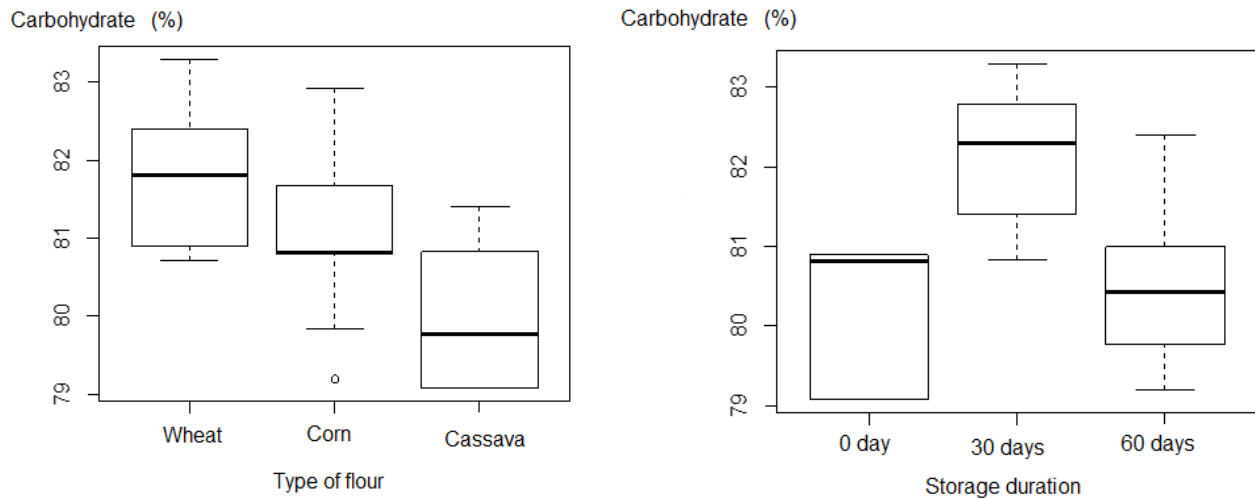


Figure 2. Carbohydrate content based on: (a) The type of flour; (b) The time of storage of flour.

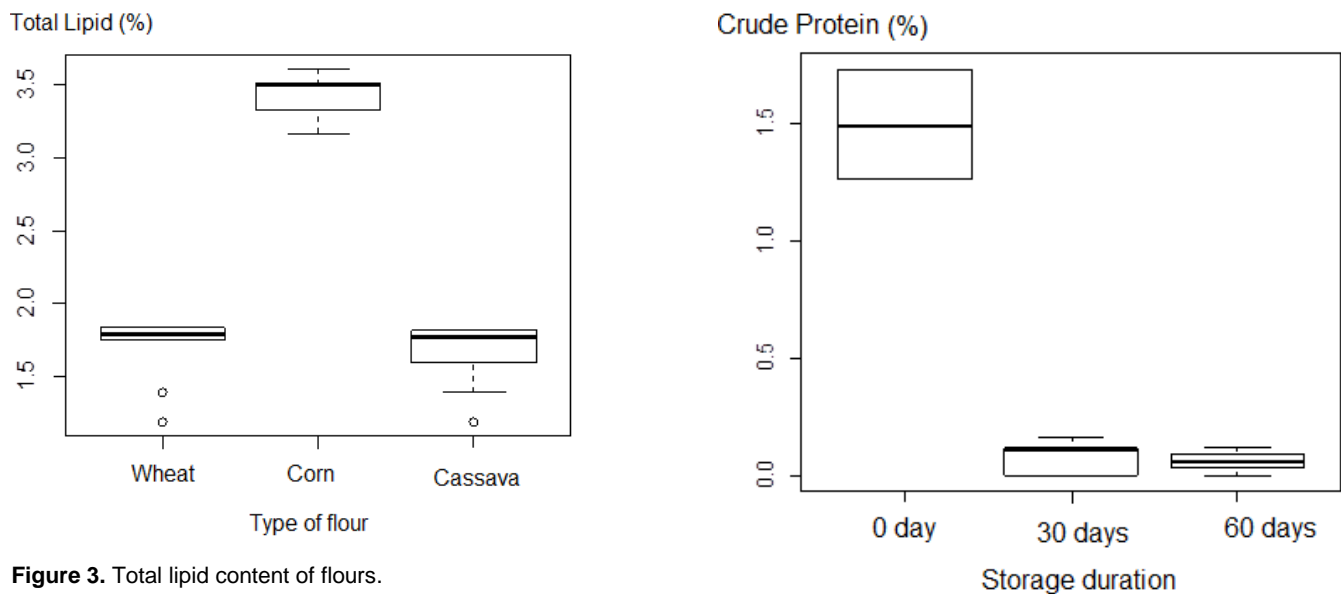


Figure 3. Total lipid content of flours.

Figure 4. Variation of crude protein based on the storage time.

normal law namely lipids, protein and ash.

Total lipids: For 3 types of flours, the total lipid content did not varied with the storage conditions and duration. This showed that the evolution of total fat content was not dependent on the duration and the storage condition. Nevertheless the Kruskal-Wallis test shows a significant p-value, which indicates the change in the quantity of lipid based on the type of flour. This variation was illustrated in Figure 3. There was a significantly higher amount of lipid in corn flour compared to wheat and cassava flour. Indeed high levels water of the wheat flour and cassava could lead to the phenomenon of lipolysis within it and encourage decreases in their lipid content.

Crude protein: It should be noted that the type of flour and the storage condition did not influence crude protein content (not significant p-value). However the Kruskal-Wallis test revealed a significant p-value, which indicated the variation in the quantity of protein according to the storage duration. This variation was illustrated in Figure 4 where there was an amount of protein higher at time T_0 , then a sharp drop at T_1 and T_2 . This decline in the rate of protein based on the duration translated the degradation of these flours, and was pronounced in partial anaerobic and aerobic conditions. It was therefore recommended to

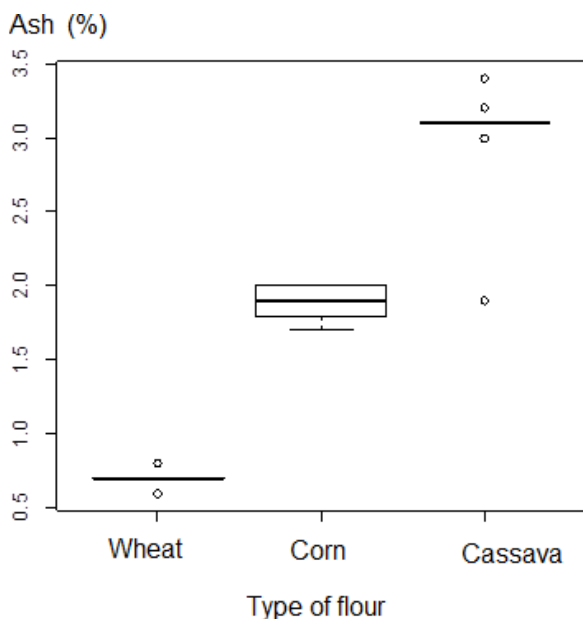


Figure 5. Variation of ash content with the type of flour.

maintain flours in anaerobic environment in order to maintain the nutritional quality.

Ash content: The duration and the storage condition did not influence ash content of flours (not significant p-value). The test revealed a significant p-value with the type of flour. This indicates a change in the quantity of ash depending on the type of flour. This variation was illustrated in Figure 5 where the highest ash quantity was obtained with the cassava flour and the lowest with wheat flour.

This disparity between the wheat, corn and cassava was mainly due to the level of efficiency of the shelling and a bad pulping of cassava. Milling of wheat was done through cutting-edge technology, which reduced considerably the amount of hull that could end up in the flour and induce a significant ash rate. High ash levels in maize and cassava flours showed quite clearly an ineffective shelling of local cereals and poor technique of transformation at the artisanal level. Therefore, there is an urgent need to improve the process of producing flour from the cassava.

Conclusion

The aim of this work was to study the impact of the storage condition and duration on the quality 3 flours of high consumption (corn, wheat, cassava). The different flours were evaluated for their physicochemical characteristics. It emerges that these nutritional parameters are influenced by the storage condition and

duration and also by the type of flour. Crude protein content was the most affected with storage. Ultimately this study advocates the total anaerobic environment for better conservation of the flour over a short period, in order to maintain the nutritional properties of the flour.

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CONFLICTS OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Preparation and analysis of goat milk mozzarella cheese containing soluble fiber from *Acacia senegal* var. *kerensis*

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Mozzarella cheese is one of the preferred ingredients for use in pizza. Goat milk is a good source of protein and calcium, possessing unique characteristics with a high proportion of small milk fat globules that contain a higher concentration of short chain, medium chain and polyunsaturated fatty acids than cow's milk. Its use in mozzarella cheese can therefore impart significant health benefits to consumers. However, despite these unique qualities, goat milk is underutilized in Kenya. Gum arabic is an excellent source of soluble dietary fiber, which can be used to boost fiber levels in cheese and other dairy products. Thus, the aim of this study was to investigate the feasibility of incorporating gum arabic as a source of fiber in goat mozzarella cheese without affecting the functionality of the cheese. Gum arabic powder at 2, 3 and 4% was incorporated into cheese during the salting process at room temperature (20 to 25°C). The functional properties of the cheese: stretchability, free oil formation and meltability were then determined. Sensory evaluation was conducted using 50 untrained sensory panelists on a 5-point hedonic scale. The results indicated that the use of gum arabic in mozzarella cheese up to a level of 3% improved the stretchability and meltability while reducing the free oil formation phenomenon. Texture, flavor, color and overall acceptability were also rated as best for samples containing gum arabic at a level of 3%. The results showed that the use of gum arabic can improve the functional properties, nutritional quality as well as sensory quality of goat milk mozzarella cheese.

Key words: Gum arabic, dietary fiber, mozzarella cheese, goat milk, functional properties.

INTRODUCTION

Cheese is an extremely versatile food product that has a wide range of flavor, textures and end uses. Cheese is a

nutrient-dense food made from cows, buffalo, goats or sheep, by coagulation. Most cheese are not eaten alone

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but as part of another food. Cheese can be classified on the basis of the country of origin, fat content (milk type), texture, manufacturing technique, physical appearance like shape or moisture content. Mozzarella cheese belongs to a class of 'Pasta filata' family, which involves the principle of skilful stretching of the curd in hot water to obtain smooth texture in cheese. The cheese is soft, white, unripened, which may be consumed shortly after manufacture. The specific melting and stretching characteristics of Mozzarella cheese is highly appreciated in the manufacture of pizza in which it is a key ingredient (Atanu, 2001). Mozzarella cheese is a mild, white fresh cheese made by a special process where the curd is dipped into hot whey then stretched and kneaded to the desired consistency. At one point, mozzarella was made only from water buffalo milk. Now, it is usually made with cow's milk. There are two forms: regular and fresh. Regular mozzarella is available in low-fat and nonfat forms and has a semi-soft, elastic texture and is drier than fresh mozzarella. Fresh mozzarella is made from whole milk and has a softer texture and sweet, delicate flavor, and is typically packed in water or whey (Sulieman et al., 2012).

Mozzarella cheese has many health benefits; it is a good source of protein, vitamins and minerals. Consumption of mozzarella cheese may protect against gout, a painful condition that results in the buildup of uric acid crystals in the joints. The calcium found in mozzarella cheese also has its contribution in body weight loss and provides protection against breast cancer and metabolic syndrome, which is a group of conditions that increase the risk of developing heart disease or stroke (Ibrahim, 2003). Prevalence of obesity in the world has prompted the reduction of high fat diet consumption and an increase in the consumption of dietary fiber (Noronha et al., 2007). Increased awareness of people on fitness and healthy lifestyle has led to an increased demand for low-calorie foods in particular for low and reduced fat cheeses (Konuklar et al., 2004). Mozzarella cheese production has continually increased because of demand in the pizza industry as pizza toppings. Its clean, mild flavor, shredability, appealing melt and stretchability make it ideal for pizza. The increased use in pizza is raising health concerns because of its calorie dense nature (Kindstedt, 2004). Thus, despite cheese being a high fat diet, it is obvious that its demand is increasing and therefore, cannot be eliminated from the diet. Therefore, there is need for production of healthier cheese. As an ingredient in food, cheese is required to exhibit functional characteristics in the raw as well as cooked forms. Melting, stretching, free-oil formation, elasticity and browning are the functional properties considered to be significant for Mozzarella cheese. When a cheese is destined for its end use, some of its unique characteristics play a significant role in the products acceptability. Reducing fat, replacing fat with fat mimetics

and enriching cheese with nutrients are some of the alternatives in this direction (McMahon et al., 1996; Mistry et al., 1996; Ryhänen et al., 2001). A reduction in fat content of cheese can be achieved by replacing it with several ingredients that provide the functionality of the missing fat. Hydrocolloids and carbohydrate-based fat replacers have been used safely as thickeners and stabilizers especially in dairy products such as sauces and dressing formulations. However, water-soluble additives such as soluble fiber tend to be washed away with whey (Lee and Brummel, 1990), further altering the composition of whey and resulting in less or no retention of that additive in cheese. Therefore, to make cheese a source of fiber, measures have to be taken not only to add fiber to milk but also get maximum retention in cheese (Fagan et al., 2006).

Gum arabic, an edible, dried, gummy exudate from the stem and branches of *Acacia senegal* is rich in non-viscous soluble fiber (Phillips and Phillips, 2011; Phillips et al., 2008; Doi et al., 2006). In Kenya, gum arabic is from *A. senegal* var. *kerensis*. In the food industry, gum arabic is used as an emulsifier, stabilizer and a thickening agent mainly in soft drinks, syrup, gummy candies and marshmallows as well as a source of soluble fiber in low calorie and dietetic beverages (Verbeken et al., 2003). Due to its low viscosity (300 cP maximum in a 1% solution), it can be used to boost fiber levels in a food or beverage without drastically altering the final viscosity. However, there are no studies on the utilization of gum arabic from *A. senegal* var. *kerensis* in goat milk mozzarella cheese.

Therefore, the aim of this study was to investigate the feasibility of enriching goat milk Mozzarella cheese with gum arabic from *Acacia senegal* var. *kerensis* as a source of fiber without affecting the functionality of this cheese.

MATERIALS AND METHODS

The present study was conducted at the Guildford Dairy Institute, Egerton University, Kenya and Jomo Kenyatta University of Agriculture and Technology, Kenya.

Goat milk was obtained from the Tatton Dairy Unit at Egerton University while gum arabic was obtained from Isiolo, Kenya.

Preparation of goat milk Mozzarella cheese at laboratory level

Ten liters of high quality goat milk was pasteurized at 63°C for 30 min and then cooled to 32°C. To adjust the pH to between 5.1 and 5.3, 16 and 18 g of citric acid was added. To enhance curd formation, 2 ml liquid rennet diluted with 40 ml of water was added. Curd cutting followed after 15 min to facilitate drainage of whey. The temperature was increased to between 43 and 45°C for another 15 to 30 min with continuous stirring. The whey was then drained and the curd hand squeezed to remove excess whey. This was followed by microwaving for 1 min, and then hand worked and stretched. Salting was done at 1.6% with addition of *A. senegal* var. *kerensis* powder at 2, 3 and 4% into the cheese. Finally, the curd

was microwaved for 30 s and then worked into ovoid shapes (Zeng, 2004).

Rheological properties

Determination of meltability

The modified Schreiber test was used to determine the meltability of cheese (Muthukumarappan et al., 1999). Five grams of cheese, 35 mm in diameter, 21-mm high disc, was heated in a forced-air convection oven (110°C) for 5 min. The sample discs were formed by boring the cheese blocks using a stainless-steel ring (35-mm i.d. and 25-mm high). The increased melted area (mm) in the cheese was determined using a graph paper. The ratio of the melted cheese area and original area was taken as an indicator of cheese meltability.

Determination of stretchability

Stretchability test was done according to Kosikowski (1982) as modified by Ghosh and Singh (1990). A sample of 10 g cheese was put in a 250 ml beaker containing $\frac{3}{4}$ of its volume of hot water maintained at 80 to 83°C in a water bath and held in the beaker for about 3 min. A glass rod was then inserted into the molten cheese sample and pulled out slowly after 3 turns by hand to ensure proper adherence of the product to the glass rod. Cheese thread formation was observed when the rod was gradually lifted. The length of the thread formed was measured in centimeters. Longer threads indicated better stretching characteristics. The length of the thread was taken as the stretchability parameter.

Determination of free oil formation

Free oil (FO) formation was determined following the modified Babcock procedure developed by Kindstedt and Rippe (1990). Eighteen grams shredded goat milk mozzarella cheese sample was weighed into 50% Paley-Babcock cheese bottles and placed in boiling water bath for 4 min to melt the samples. 20 ml of distilled water (57.5°C) was added and the samples centrifuged at 0.224 g (27.87π rads/s or 13.93 Hz) at 57.5°C for 10 min. A 1:1 mixture of methanol and distilled water was added to attain a final volume in the calibrated portion of the neck. The samples were centrifuged for 2 min and then rocked gently for 10 s to dislodge any trapped oil droplets. The bottles were centrifuged again for 2 min, rocked for 10 s, and then centrifuged for a final 2 min. The bottles were tempered in 57.5°C water bath for 5 min before addition of glymol to facilitate reading of the calibrated neck. FO was calculated as a percentage in cheese.

Proximate analysis

The proximate chemical analysis of laboratory-made goat milk mozzarella cheeses were carried out to determine crude fiber, protein, moisture content and fat content. Crude fiber content was done following the Prosky method (AOAC Method 985.29), crude protein the AOAC method 920.123, moisture content following AOAC method 926.08 (AOAC, 2000) while the fat content was determined following the ISO 3433:2008 (IDF 222, 2008) method.

Sensory evaluation

Sensory analysis was conducted using untrained panelists. A panel

of 50 was selected to evaluate cheese on a 5-point hedonic scale rating, (5- like extremely, 4- like moderately, 3- neither like nor dislike, 2- dislike moderately and 1- dislike extremely) for appearance, texture, flavor and overall acceptability (Meilgaard et al., 2006).

Statistical analysis

The experiment was laid out in a completely randomized design (CRD) with 3 replications. To increase precision, the experiment was repeated 4 times. Data on functionality tests, proximate analysis and sensory analysis were analyzed using Statistical Analysis System (SAS) package, version 9.1.3 (SAS, 2006). Analyses of variance were performed using Generalized Linear Model (GLM) procedure. Significant differences were determined at 5% level of significance and means separated using least significant difference (LSD) test to evaluate the influence of gum arabic addition on the functional properties and acceptability of goat milk mozzarella cheese. The data are presented as mean \pm standard deviation.

RESULTS AND DISCUSSION

Effects of gum arabic level on the functional properties of goat milk mozzarella cheese

The results of functional properties of goat milk mozzarella cheese containing gum arabic from *A. senegal* var. *kerensis* are presented in Table 1.

Meltability

Meltability is the ability of cheese particles to flow in a continuous uniform melted mass (Kindstedt and Fox, 1993). Addition of gum arabic had non-significant effect ($P \geq 0.05$) on the meltability of mozzarella cheese. However, samples containing 4% gum arabic had the highest meltability value (Table 1). Thus, gum arabic has the potential of improving the meltability of mozzarella cheese when added at higher levels. According to Fife et al. (1996), low fat cheeses and part-skim mozzarella cheese do not melt. Reduction of fat content in mozzarella cheese reduces the meltability value. However, in this study, despite the reduction in fat content, there was no effect on the meltability value. This is possibly because gum arabic can give the functionality of fat in cheese. Thus, gum arabic at low levels can be used as a fat replacer with minimal alteration in meltability of mozzarella cheese. This is in agreement with Oberg et al. (2015) who used modified corn starch and xanthan gum as fat replacers in low fat mozzarella cheese where they improved the meltability of the resulting cheese.

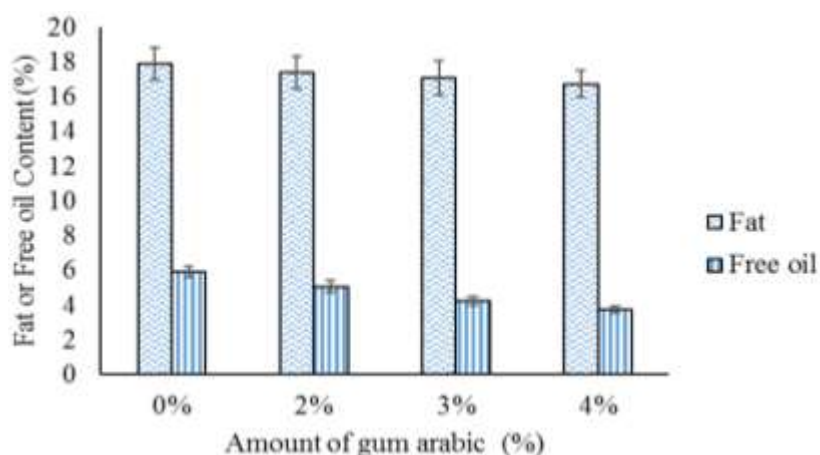
Free oil formation

Free oil formation/oiling off is regarded as a defect of this

Table 1. Functional properties of goat milk mozzarella cheese containing gum arabic.

Gum arabic level (%)	Meltability (mm)	Free oil (%)	Stretchability (cm)
0 (Control)	15.67 ± 1.27 ^a	5.92 ± 0.74 ^a	43.83 ± 0.75 ^c
2	16.43 ± 1.40 ^a	5.08 ± 0.86 ^{ab}	45.50 ± 1.38 ^b
3	16.60 ± 1.13 ^a	4.25 ± 0.61 ^{bc}	47.33 ± 1.21 ^a
4	16.73 ± 1.05 ^a	3.75 ± 0.52 ^c	41.33 ± 1.21 ^d

Means are presented as mean ± standard deviation. Means in the same column with different letters are significantly different ($P < 0.05$).

**Figure 1.** Comparison between the fat content and free oil formation in mozzarella cheese.

type of cheese when melted on the top of pie. The excessive free oil in Mozzarella cheese is of major quality problem. There was a significant decrease ($P < 0.05$) in free oil formation with an increase in gum arabic level (Table 1). Control samples had the highest free oil formation. However, this was not significantly different ($P \geq 0.05$) from the sample containing 2% gum arabic. Comparison between the amount of fat and the free oil formation for goat milk mozzarella cheese containing gum arabic is shown in Figure 1.

There was a significant positive correlation ($r = 0.68283$; $P = 0.0002$) between free oil formation and the fat content of goat milk mozzarella cheese. It appears that, the slight reduction in fat content and increase in gum arabic level caused a significant ($P < 0.05$) reduction in free oil formation. Kindstedt et al. (1992) reported similar results when a little emulsifying salt was added to mozzarella cheese, resulting in a decrease in free oil formation. The addition of emulsifying salts to mozzarella cheese causes a change in the polymorphic framework of cheese due to the emulsifying properties of the salts (Tunick et al., 1989) and thus the decrease in the free oil formation. Gum arabic has been found to have both

hydrophilic and amphiphilic properties that enhance its ability to bind water as well as fat in food products (Mugo, 2012; Ray et al., 1995; Randall et al., 1988). The reduction of free oil formation in goat milk mozzarella cheese containing gum arabic can be attributed to the emulsifying abilities of gum arabic.

Stretchability

Stretchability is defined as the ease and extent to which melted Mozzarella can be drawn to form string (Gunasekaran and Mehmet, 2003). There was a significant increase ($P < 0.05$) in stretchability with gum arabic level increase up to 3%. In addition, increasing gum arabic level beyond 3% resulted in a decrease in stretchability (Table 1).

Similar results were observed when xanthan gum was added in mozzarella cheese. According to Oberg et al. (2015), xanthan gum functioned best as a fat mimetic, producing a low fat string cheese that most closely visually resembled commercial string cheese made using low-moisture part skim (LMPS) milk. Fat mimetics act through binding extra water, which creates a lubricity

Table 2. Proximate composition (%) of mozzarella cheese containing gum arabic.

Gum arabic level (%)	Moisture	Protein	Fat	Fiber
0 (Control)	43.50 ± 3.22 ^a	28.28 ± 1.90 ^a	17.92 ± 2.29 ^a	0.00 ± 0.00 ^a
2	42.40 ± 1.63 ^a	27.32 ± 1.30 ^{ab}	17.42 ± 2.27 ^a	1.74 ± 0.16 ^b
3	42.01 ± 3.05 ^a	27.25 ± 1.07 ^{ab}	17.08 ± 2.40 ^a	2.44 ± 0.08 ^c
4	41.01 ± 1.91 ^a	26.07 ± 1.15 ^b	16.75 ± 1.94 ^a	3.41 ± 0.30 ^d

Means are presented as Mean ± SD. Means on the same column with the same letter are not significantly different ($P \geq 0.05$).

similar to full-fat products. However, they cannot replace the non-polar properties of fat such as flavor carrying capacity (McMahon et al., 1996). Gum arabic, a binder of moisture in dairy products (Mugo, 2012) was able to bind moisture in mozzarella cheese resulting in stretchability improvement in the final mozzarella cheese.

Further increase to 4% gum arabic significantly ($P < 0.05$) reduced the stretchability score. The stretch properties of mozzarella depend on the interactions between casein micelles. The more the casein network is interconnected, the more the cheese stretches. On the other hand, if the interaction between casein micelles is lost, the stretchability of mozzarella is decreased (Johnson, 2000). Adding more gum beyond 3% may have reduced the casein-casein interaction and thus the decrease in stretchability. Furthermore, according to Johnson (2000), fewer interactions would result in better melting properties which is observed at 4% gum level.

Effect of gum level on the proximate composition of goat milk mozzarella cheese

The results of proximate composition of goat milk mozzarella cheese containing gum arabic are presented in Table 2. Addition of gum arabic slightly reduced the moisture content of the resulting mozzarella cheese although the difference was not significant ($P \geq 0.05$). Similar results were reported when xanthan gum was used as a fat mimetic in low-moisture part skim (LMPS) mozzarella cheese without any increase in moisture content (Oberg et al., 2015). The reduction in moisture content may be attributed to the low moisture content of gum arabic since the gum was incorporated in dry form. Further study can be conducted to utilize gum in solution form since it has shown an increase in moisture content when guar gum was added in solution form (Oliveira et al., 2011). The moisture content values of 45 to 52% (Table 2) are in the range of cheese classified as low moisture mozzarella cheese (Jana and Mandal, 2011).

The protein content of mozzarella cheese ranged between 26.07 ± 1.15 and 28.28 ± 1.90%. This was lower but comparable to the work of Osman et al. (2009) for cow milk mozzarella cheese. In their study, they reported

the protein content of mozzarella cheese to be 23.33 ± 2.12%. There was a significant decrease ($P < 0.05$) in protein content with addition of gum arabic. Control samples with no gum had the highest protein content which was not significantly different ($P \geq 0.05$) from the samples containing 2 and 3% gum arabic. Addition of gum arabic to 4% resulted in more reduction in protein content, which was significantly different ($P < 0.05$) from the control sample. This was expected since gum arabic has very low protein content (4.55%) as compared to cheese. As shown in Figure 2, there was a decrease in the stretchability of the resulting cheese indicating a possible connection between the protein content and the stretchability of mozzarella cheeses. This is because the melt and stretch of cheese, are determined by the interaction of casein molecules (Lucey et al., 2003).

Addition of gum arabic in mozzarella cheese significantly ($P < 0.05$) increased the amount of dietary fiber in cheese. At 4% gum arabic level, highest significant ($P < 0.05$) fiber content was recorded to be 3.41 ± 0.30%. This is because of the high levels of fiber in gum arabic. Analysis of gum arabic used in this study showed that it had dietary fiber content of 78.099%. Since milk is deficient in dietary fiber, addition of gum arabic resulted in a significant increase in fiber levels in the resulting cheese. Therefore, the use of gum arabic in goat milk mozzarella cheese has the potential of not only reducing the fat content but also improving the nutritional quality of the cheese, thus making it healthier (Ryhänen et al., 2001).

Effect of gum level on the sensory quality of goat milk mozzarella cheese

The results of sensory properties of goat milk mozzarella cheese containing gum arabic from *A. senegal* var. *kerensis* are listed in Table 3. Addition of gum arabic affected the sensory properties of goat milk mozzarella cheese. Texture rating was highest in the 3% gum arabic containing cheese with a mean of 4.00 ± 1.09 which was not significantly different ($P \geq 0.05$) from the one with 2% gum arabic. Further addition to 4% negatively affected the texture of the resulting cheese. According to Lobato-

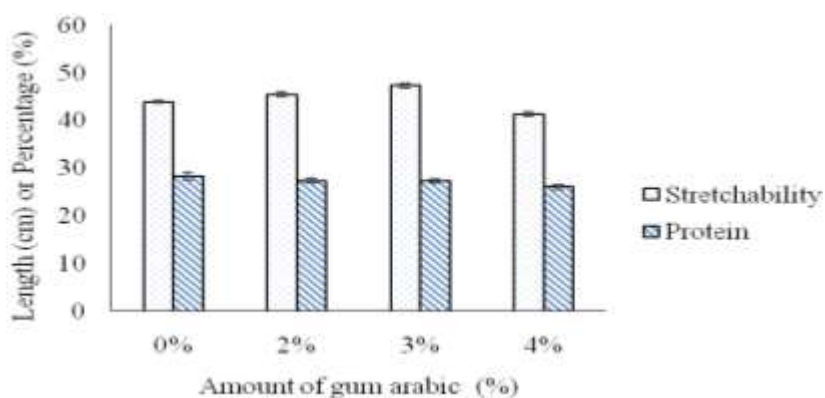


Figure 2. Comparison between the protein content and stretchability of goat milk mozzarella cheese.

Table 3. Sensory properties of goat milk mozzarella cheese containing gum arabic.

Gum arabic level (%)	Sensory attributes			
	Texture	Flavor	Color	Overall Acceptability
0	3.44 ± 1.30 ^b	3.38 ± 1.29 ^b	3.82 ± 0.96 ^{ab}	3.30 ± 1.40 ^b
2	3.94 ± 0.84 ^a	4.30 ± 0.91 ^a	4.02 ± 0.82 ^{ab}	4.08 ± 0.90 ^a
3	4.00 ± 1.09 ^a	4.16 ± 0.96 ^a	4.16 ± 0.68 ^a	4.06 ± 0.82 ^a
4	3.40 ± 1.14 ^b	3.70 ± 1.20 ^b	3.70 ± 1.04 ^b	3.80 ± 1.14 ^a

Means presented as mean ± SD (standard deviation). Means on the same column with the same letter are not significantly different ($P \geq 0.05$).

Calleros et al. (2006) as fat content is reduced, more non-interrupted protein zones compose the cheese structure. Consequently, a high degree of cross-linking of protein molecules occurs, resulting in three-dimensional networks exhibiting high resistance to deformation. Oberg et al. (2015) indicated the use of xanthan gum at a level of 1% to improve the texture of mozzarella cheese as compared to control samples with no gum. In addition, the use of guar gum and gum arabic have been reported to improve the texture of cheese (Lashkari et al., 2008).

Flavor rating was highest in the gum arabic containing samples as compared to the control samples. Samples with 2% gum arabic were rated highest followed by 3% samples which were not significantly different ($P \geq 0.05$) from each other. Control samples and the sample containing gum at 4% were not significantly ($P \geq 0.05$) different although 4% samples had a higher rating. These results indicate an improvement in the flavor of the resulting product unlike the results of McMahan et al. (1996) who argued that a reduction in fat would affect the non-polar properties of fat such as flavor carrying capacity. However, these results are true when gum level was increased to 4%. It appears that the reduction of fat content in the 4% gum arabic containing sample affected

the flavor carrying capacity of the fat. Other researchers have reported the ability of gum arabic to encapsulate flavors and aromatic compositions in food products (Kennedy et al., 2011) which may explain the retention of flavors in goat milk mozzarella cheese.

Color rating was highest at 3% gum arabic which was not significantly different ($P \geq 0.05$) from 2% and the control sample. The sample containing 4% gum had the lowest rating. According to Mistry (2001), low fat cheeses have undesirable color as compared to their full fat counterparts. Despite the minimal reduction in fat content, the rating for color was high for gum arabic sample at 3% addition. This means that, gum arabic can be used at this level with minimum effect on the color of goat milk mozzarella cheese. However, further addition seems to affect the color rating since more fat was replaced at 4% gum addition. Overall, samples containing gum arabic were significantly ($P < 0.05$) rated higher as compared to the control. Samples with 2% gum Arabic had the highest rating although not significantly different ($P \geq 0.05$) from the samples containing gum arabic at 3 and 4% in that order as shown in Figure 3. This means that gum arabic has potential for improving the appeal of goat milk mozzarella cheese. Similar results were

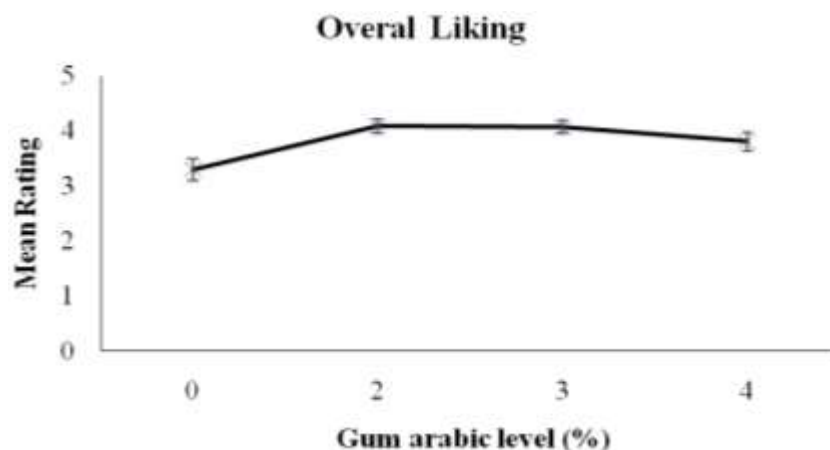


Figure 3. Overall acceptability of goat milk mozzarella cheese.

reported for other dairy products including yoghurt and ice cream (Mugo, 2012; Belitz et al., 2009).

Conclusion

The results indicated that the use of gum arabic in goat milk mozzarella cheese up to a level of 3% improved the meltability while reducing the free oil formation. In addition, there was no significant effect in stretchability of mozzarella cheese. A significant reduction in protein content and an increase in fiber content of the resulting cheese was recorded. There was also a slight reduction in fat content as well as the moisture content of the resulting cheese. Texture, flavor, color and overall liking were best for samples containing gum arabic at a level of 3%. The results of this study indicate that the use of gum arabic has the potential of improving the functional properties as well as the nutritional composition of goat milk mozzarella cheese. The commercialization of the goat milk mozzarella cheese containing gum arabic from *A.cacia senegal* var. *kerensis* has the potential of improving the standard of living of communities in arid and semi-arid lands of Kenya where the raw materials are found. Incorporation of the gum in cheese will contribute to the sustainability of goat farming with the use of goat milk aiding in addressing the challenge of goat milk marketing. It is also worth noting that most of the goats are reared in arid and semi-arid lands where gum arabic is found, hence this work will contribute to their improved standard of living by creating a market for these produce.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Food insecurity in the *green famine* belt of Ethiopia: Extent and severity in Belo-jiganfoy District, Benishangul-gumuz region

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The *green famine* belt of Ethiopia is customarily viewed as food secure area only due to relatively adequate rainfall and green vegetation cover. In contrast, this paper argues and shows that the food insecurity condition termed as “green famine” has always existed in the belt. Accordingly, the paper examined the extent and severity of food insecurity based on a cross-sectional survey of 220 households in Belo-jiganfoy district. A structured questionnaire was employed to collect data. A household food balance model was used to determine the food insecurity status and then to compute the head count ratio and food shortfalls index for determining the extent and severity of food insecurity respectively. The result showed that food insecurity was widespread and deep-rooted. The head count ratio showed that about 72% of the surveyed households were food insecure. The food shortfall index showed that on average households were 48% far below the food security threshold. The household food insecurity access prevalence showed that about 62% of the respondents were food insecure at different levels of severity: 21% mildly, 23% moderately, and 18% severely food insecure. Small-scale irrigation, wage labor, family size, land size, livestock, off-farm income and household head education were significant determinants of food insecurity. Therefore, it is safe to conclude that the extent and severity of food insecurity in the *green famine* belt is at best similar with, and at worst more than, the situation in the drought-prone and non-green famine areas of Ethiopia.

Key words: Food insecurity, extent, severity, determinants, Western Ethiopia.

INTRODUCTION

Food security is defined as “food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life”

(Canali and Slaviero, 2010). In other words, food insecurity occurs when people fail to meet the above definition and famine occurs when people face extreme level of food shortages revealing extreme hunger and/or

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starvation. Households that face food shortages on a permanent basis are termed as chronically food insecure (Degefa, 2005) while those who face it when hit by disasters or shocks are termed as transitorily food insecure; and when transitory food shortages are cyclical, it is termed as cyclical or seasonal food insecurity (Brown and Amdissa, 2007). In Ethiopia, chronically poor and food insecure people are found throughout the country although these characteristics are used to define the conditions of drought-prone areas. On the other hand, food insecurity in Western Ethiopia in general and in Benishangul-gumuz region in particular is generally seasonal and/or transitory in nature (BGR 2004). However, close field observations reveal chronic nature of food insecurity for the majority of the households in the region.

It should be noted that the causes of the known famines and hunger events of Ethiopia are almost entirely attributed to natural calamities such as drought, high variability of rains, and crop pests (Degefa, 2005). Evidences show that drought has been exacerbated by high population pressure and the resulting land degradation causing deterioration of food production (Berhanu, 2001). With this premise, historical famines and the present day chronic poverty and food insecurity could be regarded as features of either the drought-prone eastern and northern parts, or high population pressure areas of central and some southern parts of the country. To this end, two wider areas where series of famine and food shortages have occurred are identified. The first covers the central and northern highlands lying from northern Shewa through Wollo to Tigray, and the second covers the areas of agro-pastoral lowlands extending from Wollo through Hararghe, Bale, Sidamo to Gamo Gofa in the South (Canali and Slaviero 2010). Consequently, research and policy interventions have generally been limited to eastern half ignoring the western half of the country. In fact, a recent work by Mulugeta (2014) tries to indicate the prevalence of famine in the southern part of Ethiopia. This is a good start as it introduces the concept of *green famine* in the green belt of Ethiopia which, like the traditional views, relates its causes to droughts and high population pressure on land resources. The customary view that attributes severe shortage of food and famine to eastern half and drought and population pressure is however contended in this paper. The paper primarily argues that *green famine* has always existed along with its unique features but not well recognized.

Ethiopia has a long history of famine and food insecurity that goes back at least to the 19th century *great famine* (Degefa, 2005) and the 20th century Wello famine (Sen, 1981). All forms of food insecurity (chronic, transitory and cyclical/seasonal) have occurred in the country although data show a declining trend in it. For example, it was approximately 52% in 1980s, and declined to 43% in 1995/96 (Devereux, 2000), to 44% in 2003 (USAID,

2004), to 38.7% in 2004/05, 35.6% in 2005/06, to 33.3% in 2006/07, and came down to 28% in 2009/10 (MoFED, 2008). Despite this, the actual number of people exposed to food shortages has remained significantly high.

In western Ethiopia (that is, part of *green famine* belt), few empirical studies showed the extent of food shortage but perhaps none showed its severity. For example, Save the Children estimated that approximately 37% of the population of Benishangul-gumuz region faces food shortage for several months each year (Save the Children, 2010 to 2015). This seems an underestimation as empirical studies in the region indicate figures that are much more than this. For example, 58.1% of the population of the region was living in poverty in 2004 (BGR, 2004). This is more than the national figure of 50% in the mid-2000s (CIDA, 2013). The empirical household level studies also show that the proportions of food insecure households in Bullen and Assosa districts were 58% (Guyu, 2014) and 85% (Dagnachew, 2004) respectively. In addition, a qualitative study entitled *villagization for transforming semi-pastoral communities in Benishangul-gumuz region* indicates the severe nature of poverty and food insecurity in the region in general and in Dibate district in particular (Guyu, 2012). According to this study, the people (mainly the indigenous ethnic group, the Gumuz) resort to wild food as coping mechanism although it is a culture of all indigenous people of the region. These figures are far more than the national figure of approximately 44% of food insecure population in 2004 (USAID, 2004) and about 33% chronically food insecure households in 2013 (CIDA, 2013). Moreover, the figures are much higher than the situation in central Ethiopia, for example, in Nonno district, Shewa, where about 21.09% of such food insecure households were found (Messay, 2013). Likewise, they are higher than the situation in the northern Ethiopia, for example, in Tigray region where about 42% of food insecure households were found (Tsegay, 2009). This shows that the food insecurity situation in the *green famine* belt in general and in *Benishangul-gumuz region* in particular is more critical than those in *non-green famine* areas of Ethiopia. Despite this fact, empirical research regarding the extent and severity of food insecurity in the district is either little or none. Research and policy focus about food insecurity in Ethiopia seems to have biased as it geared towards northern, eastern and southern parts. Thus, this study is valuable in that it contributes to the existing literature about food security/insecurity by highlighting the situation of food insecurity in the western Ethiopia, which narrows the geographical gap in food security literature. Accordingly, the study aimed at examining the extent and severity of household food insecurity employing different rigorous approaches, tools and indicators. The findings may awaken policymakers, researchers and other stakeholders to consider this part of the country, without which overall national food security challenges may not

be effectively addressed.

MATERIALS AND METHODS

The study area

Green famine belt is generally located in western half of Ethiopia where Benishangul-gumuz region is a part. The region is located between 09°17' to 12°06' Northing and 34°10' to 37°04' Easting. According to the region's official report, it has an area of 50380 km² with altitude ranging from 580 to 2731 m above mean sea level. Agro-ecologically, it is divided into three: 75% of *kola* (lowlands below 1500 m with tropical climate), 24% of *Weina dega* (midlands between 1500 and 2500m with temperate climate) and 1% of *Dega* (highlands above 2500 m with cold climate). Average annual rainfall varies between 800 and 2000 mm. Depending on the place and season, the minimum daily temperature ranges from 12 to 20°C while the maximum ranges from 20 to 25°C in rainy season and rises to 35 to 40°C in the dry season. It has a population of 670,847, of which nearly 86% live in rural areas (CSA, 2008).

Observation shows that Belo-jiganfoy sufficiently represents the region in terms of physical, cultural, socioeconomic, and demographic characteristics as well as ethnic composition. The absolute location of the district center (Soge town) is at 11° 18'43" North and 36° 12'57" East (FDRE-ERA, 2008). The district lies between 1100 and 1450 masl, which experiences nearly the characteristics of lowland. Its rains are mono-modal type that begin in April/May and ends in October/November. The daily average temperature during rainy season ranges between 20 and 25°C while the minimum temperature ranges between 12 and 20°C depending on the season and altitude. Staying for at least eight months every year, rains of the region is sufficient for food production in terms of amount and distribution. In this regard, the case study area resembles the whole *green* belt of Ethiopia. As it is located in the western Ethiopia, Belo-jiganfoy experiences longer duration of rainy season. The district, like most parts of the region has extensive fertile arable land, natural forest, surface and ground water, and mineral resources. Accordingly, the livelihood of households in the district depends largely on land resources through mixed farming, fishing and collection and hunting of wild foods. Despite availability of large rivers such as Didessa and Anger, small irrigation is little practiced.

Population pressure is not a major problem in Belo-jiganfoy district as it has a very low density (18.5 persons/km²) although growing from time to time. It consisted of total population of 27,381. Of this 53% were males and 47% were females while 90.84 and 9.16% were rural and urban populations respectively. The average family size was 5.1. The rural population of the district (90.84%) is much higher than the national average (85%) implying that the lives of most people in the district depend on agriculture. Moreover, about 42% of the population was under 15 years old, 56% between 15 and 64 and only 2% was above 64 (CAS, 2008:38). The major ethnic groups of the district include Gumuz, Berta, Mao, Amahara and Oromo while few others also live in it. The cultural interaction of these different ethnic groups and the resulting experiences is what is termed as *ethno-culture* (Guyu, 2014). The religious composition of an area has its own impact on local and national development efforts. In rural areas, it may affect agricultural productivity via the number of days devoted to working in farms and religious festivals. Almost all types of religious practices are found in Belo-jiganfoy district. Data show that the district consists of 46.4% followers of Orthodox Christianity, 44.6% protestant Christianity, 16% Catholic, 46% Muslim, 2.2% traditional healers and 0.8% followers of undefined beliefs (CSA, 2008).

The livelihood of almost all population of Belo-jiganfoy is founded on agriculture in the mixed fashion (arable and livestock farming). Most indigenous people of the district have been mainly shifting

cultivators. Major cereal crops such as maize and sorghum, legumes such as haricot beans and soya beans, oil seeds such as sesame and, fruits such as mangoes are produced. Livestock production is also practiced in the district although the potential remains unexhausted. Cattle, goats, sheep, poultry and bees are better. Belo-jiganfoy district has only one main market center at Soge which serves twice a week. Following the regional pattern, it has weak road network that covers only 18 km (FDRE-ERA, 2008). Mobile telephone service is functional in most areas of the district. Electricity line that is not functional for much of the time is available presently only in Soge town. The rural areas of the district depend on biomass as a source of energy. Protected water for domestic use is very limited in the district. According to district office information, the health coverage of the district had reached 58% but characterized by poor quality while there were 11 primary and 1 secondary school showing 73% coverage of primary education in the district. One credit service institution is available at the district center, Soge town.

Research process

A cross-sectional survey was conducted in Belo-jiganfoy district, Benishangul-gumuz region, western Ethiopia during the last week of August in 2013. The district was purposively selected as it can generally represent the *green famine* belt in terms of physical, socioeconomic and cultural backgrounds.

Data were collected from 220 randomly selected rural households considering the indigenous and non-indigenous ethno-culture groups using structured questionnaire. Data were analyzed using the Statistical Package for Social Sciences (SPSS) version 19. The extent and severity of household food insecurity was measured and analyzed using dietary energy supply (DES) and household food insecurity access scale using its prevalence (HFIAP), a categorical indicator of severity of food insecurity. Finally, the impact of socioeconomic and demographic characteristics of the surveyed households on food insecurity was examined using binary logistic regression model.

Different methods were used to determine the food insecurity status of each household. The household food balance model is a simple balancing equation that calculates the net food or net DES as the difference between the gross food available to a household from all sources and the total food disposal for any reason (Equation 1).

$$\text{Net Food/DES} = (\text{GF} - \text{FDSPL}) = (\text{OP} + \text{FP} + \text{FB}) - (\text{FS} + \text{SR} + \text{PHL}) \quad (1)$$

Where; NF/DES = Net food/dietary energy supply; GF = gross food; FB = food borrowed; FDSPL = food disposal ; FS = food sold; OP = own produce; SR = seed reserved; FP = food purchased; PHL = post-harvest lost.

The net food obtained from this equation for each household is compared against the minimum recommended threshold amount of 2100 kcal/ADE/day. The net DES which considers the amount of calories in each food item was used to determine the net DES available to each household. The amount of calories for each household was obtained by converting respective amount of net food into kcal equivalent based on conversion factors (Hoddinott, 1999). For example, the suggested equivalence of 1kg of millet is about 3390kcal (Hoddinott, 1999). The kcal consumption of each household is compared with the nationally recommended minimum amount for a healthy adult person per day of 2100 kcal (Messay, 2013) to identify food secure and food insecure households. Then, the head count ratio was calculated based on the food security status using the following formula:

$$\text{HCR} = [(n/N) \times 100] \quad (2)$$

Where, HCR is head count ratio; n = number food insecure households; N = Total number of sample households.

This ratio shows the extent of food insecurity in terms of the percent of food insecure households in the population but tells us little about the severity/depth of food insecurity (Frehiwot, 2007). As a result, the food shortfall index (FSI) was determined to solve this problem based on the following procedure:

$$FSI_i = [(MRF - TFA_i) / MRF] \quad (3)$$

Where; FSI_i is food shortfall index of i^{th} food insecure household; MRF is the minimum recommended food and; TFA_i is Total Food Available for i^{th} food insecure household. The total FSI is then calculated as the average value of the sum of FSI_i for all surveyed households (N) and expressed as follows:

$$\text{Total FSI} = \Sigma[(FSI_i / N)] \quad (4)$$

HFIAPs also a categorical measures used as indicator of access to food security/insecurity, which involve complex analytical procedures when determining their respective scale/index (Coates et al., 2007).

Finally, determinants of household food insecurity were analyzed using logistic regression model for its advantage over other regression models. Different options of models are available for analyzing a categorical dependent variable. But, logistic regression and discriminant analysis are the two widely used statistical methods used for analyzing data with categorical outcome variables (Tsegay, 2009). Discriminant analysis is often employed if all predictors are continuous and normally distributed; logit analysis is often used if all predictors are categorical, and logistic regression is often chosen if predictors are mixed and/or if they are not nicely distributed (Karl, 2011). In other words, logistic regression makes no assumption about the distribution of explanatory variables for best prediction of binary outcomes. The dependent variable (Y_i) is defined as 1 if a household is food insecure or 0 if food secure (i range from 1 - 220) and given as follows:

$$Y_i = \beta + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_n X_n + e \quad (5)$$

Where; Y_i is the dependent variable; β is a constant value that represents the Y intercept; $\beta_1, \beta_2, \beta_3, \dots, \beta_n$, coefficients of $X_1, X_2, X_3, \dots, X_n$ respectively, and $X_1, X_2, X_3, \dots, X_n$ are explanatory variables, and e is error term.

Ethical issues were also maintained in order to increase the reliability and validity of the information. Ethical clearance was obtained from the post graduate committee of Addis Ababa University. It was addressed during both data collection and analysis. Permission was obtained from the capacity building office of the district prior to data collection. Moreover, informed consent was obtained from each respondent by explaining the purpose of the research, dispersion of the results, and participant rights prior to their participation in the survey.

RESULTS AND DISCUSSION

Sources of food for the surveyed households

As elsewhere in Ethiopia, rain-fed arable farming is the main source of food availability for almost all rural households in Belo-jiganfoy district. The study showed that about 99% of the total land cultivated by the surveyed households was through rain-fed system and only about 1% was cultivated through small-scale irrigation. Similarly, 1.5 and 98.5% of the total yield was

produced through small-scale irrigation and rain-fed cultivation respectively. Vegetables, fruits and to some extent maize were the major crops produced through small-scale irrigation. This is almost the same as the national figures that showed rain-fed agriculture and small-scale irrigation accounted for about 98 and 1.2% of annual production respectively (CIDA, 2013). This implies that the potential of irrigation in general and small-scale irrigation had not been fully exploited, which might have probably caused the prevailing condition of food insecurity.

The result (Table 1) indicates that the annual gross available food for the surveyed population from all sources was 7198.2 quintal (qtl hereafter). This was expected to feed the total household size of 922.82 in adult equivalent (ADE hereafter) with average size of 4.20. The result also showed that almost all of the food for the surveyed households (that is, about 95%) came from own production. The next better source of food was wild food which accounted for about 4% of the total gross food available households. This was followed by food purchase that accounted for about 1% and borrowing as a food source was almost absent as it accounted for about 0.2% of the total food available to the respondents. The dominance of own produce as food source should not be miraculous as it is reflected in the overall trend of rural communities elsewhere in the world in general and in Ethiopia in particular. In principle, the food obtained from all of these sources may not be eaten. Some of it might have been sold, reserved, or lost through different ways such as attacks from rodents and infestation of grain pests. With these assumptions, data regarding grain sold, seed reserved and grain lost were collected and computed. Finally, the total amount of food (qtl) was deduced from total amount obtained from all sources. The result showed that there was about 3709 qtl net food available to the surveyed households resulting in average food amount of 4.02 qtl/ADE/year (Table 1).

The extent of food insecurity

On average the respondents produced 4.02 qtl/ADE/year of food from different sources. This was a little less than the average household size of 4.20 ADE (Table 1). This roughly shows the prevalence of food shortfall in the district. Contrary to this was that the average net food (4.02 qtl) was much more than the minimum recommended grain equivalent of food (that is, 2.25 qtl) suggesting that the respondents were on average food secure. But, both are not good indicators of household food security situation as disparity exists among households in their access to food and amount produced as well as in the calorie content of each food item. The dietary energy supply (DES), proxy indicator of consumption, was used to show the extent and severity of the food security/insecurity situation and harmonize the above contrasting results. This was because DES

Table 1. Food available to the surveyed households from all sources.

Food source	Amount produced (qtl) and household size (ADE)					
	Total	%	Mean	Std	Min	Max
Cereals	5850	81.27	25.86	18.57	0.00	106.00
Legumes	274.50	3.81	1.68	6.48	0.00	48.00
Oil seeds	448.05	6.23	3.45	7.15	0.00	90.50
Vegetables and fruits	98.25	1.37	0.45	1.65	0.00	10.00
Meat (domestic)	157.96	2.19	0.37	0.29	0.00	1.28
Total own produced	6828.76	94.87	30.01	22.44	0.06	131.15
Grain purchased	81.51	1.13	0.29	0.97	0.00	5.00
Grain borrowed	12.5	0.17	0.05	0.27	0.00	2.00
WEFs (all)	275.43	3.83	13.19	2.3	0.00	20.50
Grand total	7198.2	100.00	-	-	-	-
Grain sold (GS)	2798.1	38.87	8.20	9.45	0.00	74.00
Seed-reserved (SR)	384.76	5.34	1.75	1.73	0.00	12.50
Post-harvest-lost (PHL) (5% of total yield)	307.19	4.27	0.71	0.51	0.01	3.26
Total deduced	3490.05	48.48	3.82	4.10	0.00	84.10
Net Food	3709.09	51.52	14.21	10.17	0.15	65.25
Household size (ADE)	922.81	-	4.20	1.65	1.68	13.65
Ave. Net Food/ADE/year	4.02	-	4.02	2.93	0.04	19.59

Meat of 1 antelope = on average 25 kg; 1 bird = on average 0.5 kg; 1 kg fish = 10 fish; 1 'medeb' cattle meat = on average 10 kg.

Table 2. Distribution of households by kcal supply and food security status.

Information type	Total	Mean	Std.	Min.	Max.	
Household size (number)	1210.0	5.50	2.41	2.00	20.00	
Household size (ADE)	922.82	4.15	1.62	1.68	13.65	
Kcal/ADE/day (FS + FIS)	388643.1	1766.6	1440.1	0.01	8899.5	
FS (28.2%)	Average hh size (ADE)	220.19	3.55	1.35	1.68	8.04
	kcal/ADE/day	220112.5	3550.2	1546.5	2107.9	8899.5
FIS (71.8%)	Average hh size (ADE)	693.18	4.38	1.66	1.94	13.65
	kcal/ADE/day	168530.6	1066.7	462.8	0.01	2069.1
DES (kal)	% of food insecure households = 71.8%					
	% of food secure households = 28.2%					
	% of both households = 100%					
Total FSI	Index = -0.48					

accounts for the variation in the calorie amount in each food item.

The result of the analysis of the DES (Table 2) showed that on average the surveyed households had net kcal of 1766.56 with Std. of 1440.1 kcal. The average kcal for the food secure and food insecure households was 3550.2 kcal/ADE/day with standard deviation of 1546.5 kcal/ADE/day and 1066.7 kcal/ADE/day with STD of 462.77 kcal/ADE/day, respectively. The result showed that about 72% of the respondents were food insecure whereas only about 28% was food secure one (Table 2).

This proportion of food insecure households is very high by the standards of some countries in Africa including Ethiopia. For example, in Kwara State, Nigeria 75% of surveyed households was food insecure (Omotesho et al., 2006). Similarly, it is alarmingly larger than the national level of incidence of undernourishment indicated in FAO's previous study in Ethiopia that showed 41% between 2005 and 2007 and 28% in 2009/10 fiscal year (FAO, 2010). It is almost similar with the finding in previous study conducted in Oromiya zone (Wollo) where drought is frequent. Here, about 81 and 74% of

Table 3. Distribution of households by HFIAP category.

Information	HFIAP categories				Total
	Food- secure	Mildly-food-insecure	Moderately-food-insecure	Severely-food-insecure	
Household (no.)	86	45	50	39	220
Percentage (%)	39.04	20.57	22.59	17.76	100
Cumulative (%)	39.08	59.65	82.24	100.0	-

households felt food insecure and food non-sufficient respectively (Degefa, 2005). This is also almost similar with the finding of a previous study conducted in Arsi zone (Dodota district) in central eastern Ethiopia that showed about 79% of food insecure households (Haile et al., 2005), an area characterized by low rainfall distribution. Moreover, the finding is much higher than the finding in northern Ethiopia: Amhara and Tigray regions as well as central Ethiopia (Nonno district in Oromya), where population density, land fragmentation and soil degradation are critical problems. The respective level of the above areas is about 56% (Frehiwot, 2007), 42% (Tsegay, 2009) and 21% (Messay, 2013) respectively. In Bullen district (located in the 'green famine' belt) too, it was 58% (Guyu, 2011) implying that food insecurity had been worsened over the past years. Within the *green famine* belt of Ethiopia (specifically in Benishangul-gumuz region), a previous study showed larger proportions of food insecure households than this. For example, a previous study conducted at household level in Bullen district showed about 58% of food insecure households (Guyu, 2014).

The overall implication of the above results is that the depth and severity of food insecurity in the *green famine* belt of Ethiopia is at best as severe as the one in the drought-prone and high population pressure areas and at worst higher than it.

The severity/depth of food insecurity

The extent and or coverage of food insecurity indicated in the above subsection may not give how severe the situation is. It merely shows the proportion of households affected without its depth. Thus, full understanding of the food insecurity situation should consider its level of severity. TFSI was used to measure the depth/severity of food shortage. The total FSI for the surveyed households was -0.48 (Table 2) indicating that on average, the food shortfall for each household was far down from the threshold (that is, 2100 kcal/ADE/day) by 48%. This mean distance from the threshold is much deeper than the case in Tigray region (32.5%) (Tsegay, 2009) located in one of the drier parts of Ethiopia. This clearly shows that food insecurity in the western part of the country in general and in the studied district in particular is much deeper and/or severe than the situation in the most

fragile northern part. Severe food shortfall is the ultimate indicator of famine conditions and was extraordinarily deeper in the study area showing that it has already turned into the *famine* conditions and hence *green famine* (Guyu and Muluneh, 2015). Thus, the total FSI of 48% was significantly deep proving that the *green famine* condition is evident in the area.

Furthermore, in order to cross check and confirm the result of the total FSI, we employed the household food insecurity access scale, which is an access related indicator of household vulnerability to food insecurity. Its categorical indicator known as household food insecurity access prevalence (HFIAP) was computed in order to examine and understand the severity and/or depth of food insecurity. The HFIAP customarily categorizes households into four severity levels as food secure, mildly food insecure, moderately food insecure and severely food insecure (Coates et al., 2007). The result (Table 3) showed that 62% of the respondents were food insecure at different levels of severity. Out of this about, 21% was mildly, 23% moderately and, 18% was severely, food insecure. Only about 39% of the respondents were found to be food secure. In the routine classification of households' vulnerability status based on kilocalorie supply, about 72% of the surveyed households was food insecure and about 28% was food secure. The result of the HFIAP was almost close to the result obtained from DES. This shows that food insecurity is severe by all measures and standards in the *green famine* belt of Ethiopia.

Determinants of household food insecurity

Socioeconomic and demographic variables that influenced household food insecurity were analyzed using forward stepwise logistic regression model. The Hosmer-Lemeshow statistic was >0.05 (0.170) showing the model fits well into the data. Regression analysis was conducted on 24 original variables thought to have influenced household food insecurity. The model produced 7 determinants whose effects on dependent variable were significant (Wald statistics <0.05 level). As a rule, linear regression predicts the category with higher value in this paper, food insecure households. The model predicted the food insecure group because they were denoted by 1 as compared to food secure denoted by 0

Table 4. Parameter estimates showing the effect of each variable.

Explanatory variable	B	S.E.	Wald	df	Sig.	Exp. (B)
Family size/ hh (number)(FSZ)	0.454	0.124	13.417	1	0.000	1.574
Off-farm income (birr)/year (INCOFF) *	-0.186	0.064	8.480	1	0.004	1.000
Educ. of hh head (years) (EDUY)	-0.164	0.049	10.958	1	0.001	0.849
Livestock size (TLU)	-0.206	0.082	6.297	1	0.012	0.814
Land cultivated/hh (LCULT)	-0.243	0.081	8.885	1	0.003	0.784
Irrigation Use (dummy) (IRRG)	-1.413	0.565	6.257	1	0.012	0.243
Wage Labor (dummy) (WLBR)	0.911	0.386	5.566	1	0.018	2.487
Constant	1.018	0.652	2.435	1	0.119	2.767

*US \$1 was 19.54 Eth. birr (Ethiopian currency) at the time of survey.

in the SPSS. Thus, each predictor in the model predicted the probability of being food insecure.

The new model is given as follow:

$$Y_i = 1.018 + 0.454*FSZ - 0.186*INCOFF - 0.164*EDUY - 0.206*TLU - 0.243*LCULT - 1.413*IRRG + 0.911*WLBR + e$$

Where Y_i is the probability of being food insecure by i^{th} household ($i = 1 - 220$).

The model fairly predicted the food insecurity occurrence (the Nagelkerke $R^2 = 0.638$) implying that about 64% of the variation in household food insecurity was explained by the model. Based on these variables, the model predicted the probability of being food insecure at 81.4% showing that food insecurity increased if the current conditions would remain the same.

The results (Table 4) showed that, as indicated in the B column, family size was positively associated with food insecurity ($B = 0.454$) implying that a unit increase in the probability of being food insecure was caused by increases in household size by 0.454. This is similar with several previous studies that showed statistically significant and positive relationship between household size and food insecurity (Haile et al., 2005; Omotesho et al., 2006; Bogale and Shimelis, 2009). The likely explanation is that many household members would be in their non-productive age and were incapable of contributing their labor about 97 dependent people per 100 economically active people existed in the region and most households depend on hoe-culture rather than on oxen-plough or other cultivation systems. In addition people in the study area are not hard workers who prefer to pass much of their working days in villages drinking alcohols (Guyu, 2016).

Off-farm income affected household food insecurity negatively ($B = -0.186$). This implies that a unit increase in the probability of being food insecure was caused by a decrease in off-farm income by 0.186. This is similar with previous studies that show negative relationship between off-farm income and food insecurity (Omotesho et al., 2006; Bogale and Shimelis, 2009). The likely justification

of the negative relationship is that households might buy food by the income they earned through off-farm activities.

Average education of household heads was also negatively related with food insecurity implying that a decrease in the number of years a household stayed at school by 0.164 increased the probability of being food insecure by one unit. This goes in line with a previous study in Ethiopia which showed statistically significant and negative relationship between level of household head education and the probability of being food insecure (Haile et al., 2005). The likely justification is that educated households are better in the timing and prediction of seasonal food insecurity occurrence. Accordingly, they might be well prepared for tackling the problem.

The TLU was also negatively associated with household food insecurity ($B = -0.206$) implying that a unit increase in food insecurity was caused by a decrease in TLU by 0.206. This finding is similar with the general literature and some previous studies (Bogale and Shimelis, 2009; Messay, 2009). The possible explanation for this is that most households had no livestock that would be sold for buying food during the times of food shortage.

The average cultivated land size per household was negatively related with food insecurity. The B value = -0.243 implies that a unit increase in food insecurity was caused by a decrease in land size by 0.243 ha. This goes in line with the theory that argues that a negative relationship exists between cultivated land size and food insecurity (Degefa, 2005). The result is also similar with many studies in Ethiopia that showed cultivated land size influences household food insecurity negatively and statistically significantly (Messay, 2009; Bogale and Shimelis, 2009). The likely explanation is that as the size of cultivated land increases, the amount of yield also increases keeping other factors constant.

Practice of small scale irrigation was negatively correlated with household food insecurity showing a unit increase in food insecurity with a 1.413 unit decrease in the practice of small scale irrigation. This goes in line with the findings of many previous studies conducted in Ethiopia which showed statistically significant and negative

relationships between irrigation use and household food insecurity (Degefa, 2005; Bogale and Shimelis, 2009). The possible explanation is that access to and use of small-scale irrigation enabled households to produce twice a year. This might have increased their access to both income and food from crop production.

Lastly, it was found that involvement in wage labor positively influenced the food insecurity of households ($B = 0.911$) although it was not significant at less than 10% level.

The odds ratio in favor of the probability of being food insecure increased by a factor of 2.478 with increased participation in labor union. The likely justification for the violation of the expected relationship between participation in labor union and food insecurity is that households were perhaps engaged in such work to cope with food shortages by earning money and buying grains.

Conclusion

The purpose of this study was to measure and understand the extent and severity of household food insecurity in the *green famine* belt (western Ethiopia) based on a case study. The study showed that food insecurity was widespread and deep-rooted. The fact that food insecurity affected about 72% of the surveyed households shows that food insecurity is widespread phenomenon and it is as prevalent as the situation in the conventional drought-prone non-green famine parts. The food shortfalls were very deep reaching 48% far below the food security threshold. Out of about 62% of food insecure households as indicated by the household food insecurity access prevalence, 21% were food insecure mildly, 23% moderately, and 18% severely food insecure. Small-scale irrigation, wage labor, family size, land size, livestock, off-farm income and household head education were significant determinants of food insecurity. Thus, any intervention measure to improve the food insecurity status of households should target at addressing these variables. Therefore, we can disprove the perception that the *green famine* belt of Ethiopia is food secure only due to a relatively adequate rainfall and green vegetation cover. Instead, it can be concluded that the extent and severity of food insecurity in the *green famine* belt is at best similar with, and at worst more than, the situation in drought-prone and non-green areas of Ethiopia.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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