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Indigenous technical knowledge and formulations of thick (*ugali*) and thin (*uji*) porridges consumed in Kenya

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Thick (*ugali*) and thin (*uji*) porridges are important sources of nutrients for millions of Kenyans. They are made from unblended or composite flours of cassava and whole milled maize, finger millet or sorghum. *Ugali* is eaten as a main meal at lunch or dinner whereas *uji* is taken as a refreshing drink any time of the day. *Uji* is also an important complementary food for children. In addition, some formulations of *ugali* and *uji* are used to manage non-communicable diseases such as cardiovascular diseases and type II diabetes. The aim of this study was to document indigenous technical knowledge on *ugali* and *uji* in Kenya. Primary information was collected through Focus Group Interviews in ten counties in western Kenya and corroborated with secondary literature. Unblended whole milled white maize and finger millet are the preferred flours for making *ugali* and *uji*, respectively. Whole milled maize, finger millet and sorghum are recommended for preparing *ugali* and *uji* for people suffering from non-communicable diseases. *Uji* prepared as a complementary food for child-feeding is usually supplemented with plant or animal proteins in order to improve its nutritional quality. The indigenous technical knowledge provided by the interviewees show that several opportunities exist for product innovations and quality and safety improvements.

Key words: Kenya, maize, finger millet, sorghum, cassava, *ugali, uji*.

INTRODUCTION

Maize (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench), finger millet (*Eleusine coracana* (L.) Gaertn) and cassava (*Manihot esculenta* Crantz L.) are important raw materials for the production of thick (*ugali*) and thin (*uji*) porridge in Kenya. However, production of these crops is less than the demand and hence considerable quantities have to be imported (Table 1). White semi-dent maize is the premier staple food crop in Kenya (KSC, 2016) with an annual production of about 3.6 million tons (Table 1). It is grown by 98% of rural farm households

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Table 1. Production and utilization of maize, finger millet, sorghum and cassava in Kenya[a].

Food item	Area planted (1000 ha)	Domestic supply (1000 metric tons)				Domestic utilization (%)					Per capita consumption (kg/person/year)
		Prod.[b]	Imp.	Exp.	TDS	Food[c]	Feed	Seed	Waste	Other	
Maize	2100	3591	112	6	3697	92	3	2	2	1	76
Sorghum	210	139	104	6	237	79	10	2	11	0	3
Finger millet	140	64	8	0	72	78	8	3	11	0	1
Cassava	64	1112	4	0	1116	97	0	0	3	0	24

[a]Adopted with modifications from FAOSTAT (2016). [b]Production plus stock changes (grains released by the government from national grain reserves). [c]Food: Refers to amount directly used as food and processed into food products. Prod.: production; Imp.: imports; Exp.: exports; TDS : total domestic supply.

and makes a large share of households' crop income (FTF, 2011). Despite the importance of maize as a national food security crop, several production constraints (Ndwiga et al., 2013; Ouma and De Groote, 2011) result in insufficient production to meet national demand (FAOSTAT, 2016). The productivity of sorghum in Kenya is about 1.7 t/ha (USAID, 2010), which is below the genetic potential of 3 to 4 t/ha (KSC, 2016). Improved sorghum varieties like Serena, Seredo, Gadam and E1291 with higher genetic potentials are increasingly being adopted by farmers (KSC, 2016).

The average mean yields of finger millet in Kenya is 2.9 t/ha (USAID, 2010). Improved varieties such as P224 and Katumani with yields reaching up to 3.3 t/ha are also being promoted by Kenya Seed Company (KSC, 2016). Cassava is an important food security crop in the semi-arid regions of Kenya (USAID, 2010), because the planting material is easily accessible; and it is drought tolerant, has a high production potential per unit of land and high return of food calories per unit energy input in its cultivation. The average cassava yield in Kenya is 15 to 20 t/ha against a potential yield of over 50 t/ha (MoA, 2010; USAID, 2010).

Thick (*ugali*) and thin (*uji*) porridges are important sources of calories and several other nutrients for millions of Kenyans. The porridges are made from unblended or composite flours of cassava and whole-milled grains of maize, finger millet or sorghum. When the flours are heated in excess water, the starch-rich slurry transforms into porridge as a result of gelatinization of starch. The main difference between *uji* and *ugali* relates to the amount of flour that is required to make the products. Less flour (about 10% w/v) is required to make *uji* than *ugali* (about 30% w/v) and hence the former can be drank or eaten with a spoon, whereas the latter is a solid paste that must be chewed before it can be swallowed (Onyango, 2014).

Uji is normally consumed as a breakfast meal or refreshment drink at any time of the day. It helps to improve appetite and, thus, is recommended for consumption a few hours before the main meal. It is an important source of energy and nutrients for complementary feeding of children below five years. *Uji* is the preferred food for invalids because they are weak and cannot consume food that requires a lot of energy to chew and swallow. In poor households, especially during famine, per capita consumption of *uji* is high because only a small amount of flour is required to make a large volume of the product, which can be consumed throughout the day. *Ugali* is eaten as the main dish for lunch or dinner with accompaniments such as vegetables and meat. Local communities also use certain recipes of *ugali* and *uji* as functional foods for the management of some non-communicable diseases, especially cardio-vascular diseases and type II diabetes.

The recipes used to make *ugali* and *uji* are variable and are dependent on the cultural practices, predominant crop grown in the area, and the price and availability of raw materials. The raw materials for making these porridges are largely prepared at home or in small-scale processing plants using rudimentary equipment and techniques.

The products have variable quality parameters due to the lack of raw material, process and product specifications. Consumption of these porridges is declining due to increasing competition from ready-to-drink beverages, such as tea and coffee; and other staple carbohydrate-rich food crops, such as rice and wheat. The aim of this study was to document indigenous technical knowledge on the preparation and utilization of *ugali* and *uji* in Kenya.

METHODOLOGY

Focus group interviews

Focus Group Interviews were used to determine ethnic practices associated with preparation and consumption of *ugali* and *uji* in ten counties in western Kenya (Siaya, Migori, Kisumu, Homa Bay, Nyamira, Kisii, Bungoma, Busia, Kakamega and Vihiga). Purposive sampling was used to select groups of 8 to 10 women in each county to participate in the Focus Group Interviews. The interviews were conducted in the months of May and June, 2016. The discussions focused on the following issues: (i) describe the preparation of flours from maize, finger millet, sorghum and cassava; (ii) identify the main unblended and composite flours used to prepare *ugali* and *uji*; (iii) describe the quality characteristics of *ugali* and *uji;* and (iv) identify *ugali* and *uji* recipes for complementary feeding of children and people suffering from non-communicable diseases such as cardiovascular diseases and type II diabetes.

Description of study site and interviewees

The administrative structure of the Kenyan state is composed of a central government and 47 county governments (Constitution of Kenya, 2010). In this study, Focus Group Interviews were conducted with women from ten counties in western Kenya. The predominant ethnic groups in these counties are the Luo in Siaya, Migori, Kisumu and Homa Bay counties; the Kisii in Nyamira and Kisii counties; and the Luhya in Bungoma, Busia, Kakamega and Vihiga counties. Other major indigenous communities that are native to these counties include the Suba and Kuria in Migori county; the Teso in Busia and Bungoma counties; and the Sabaot in Bungoma county. According to the latest Kenya Population and Housing Census data of 2009 (KNBS, 2016), the population of these counties was 9.8 million, which constituted 25% of the national population (38.6 million). The sample size of respondents in this study was 134 people. The age group distribution of the interviewees was 26, 44 and 30% for <30, 30-50, and >50 years, respectively. The ages of the interviewees were considered an important input variable in the discussions because of anticipated variability due to the influence of society, peers, culture, and experience.

Focus Group Interviews were used to collect the data in order to capture the diversities of porridges in the counties and to evaluate consumer preferences. The western region of Kenya was selected for the study, because the wide variety of recipes and techniques used to make porridges in this region can provide a representative view of the national consumption pattern. Purposive sampling was used to select respondents with knowledge and experience on past and current practices of making and consuming *ugali* and *uji*. Only women were interviewed, because they play a major role in meal planning and preparation in most families; nurse and feed children; and select food for invalids and people suffering from non-communicable diseases such as cardiovascular diseases and type II diabetes.

RESULTS AND DISCUSSION

Consumption of maize, sorghum, finger millet, and cassava in Kenya

Maize is not an indigenous crop in Kenya, but several government policies have ensured that it is the primary staple food in the country (Smale and Jayne, 2003). Maize accounts for a significant portion of dietary protein intake in the country despite the fact that it is deficient in essential amino acids like lysine and tryptophan (Nuss and Tanumihardjo, 2011). Nutritional interventions like the use of Quality Protein Maize (QPM) that is bio-fortified with tryptophan and lysine have been tried and accepted in Kenya (De Groote et al., 2014). White semi-dent maize is the most popular variety for making food products in Kenya, but local landraces of yellow and coloured dent maize are also widely produced.

Maize is eaten in many forms in Kenya. Whole-milled or sifted maize flour is used to make *ugali* or *uji*. The whole cob can be boiled or roasted and eaten directly from the cob. Maize grains can also be mixed with pulses and boiled in water to make *githeri*. African bread (*estata*) is made from maize flour and ripe banana. The dough is moulded into round balls, which are then wrapped in cooked banana leaves and steamed over a pot of boiling water. Another ready-to-eat maize snack is called *makhalange* in Bungoma and Busia counties or *zimbare* in Kakamega and Vihiga counties. Whole-milled maize is soaked in water to make a thick paste, which is fermented for 3 days. The paste is then slightly roasted and sun-dried. It is eaten as a dry snack or gruel after reconstitution in warm water. The fermented paste can also be made into an opaque alcoholic beverage (*busaa*) by adding sorghum or finger millet malt.

The national per capita consumption of finger millet is 1 kg/person/year (Table 1). More than 75% of finger millet produced in Kenya is used as human food (Table 1). Finger millet flour is preferentially used to make *uji* rather than *ugali*, because its supply is limited and hence it fetches a higher market price. The limited supply and high cost of finger millet is because few farmers grow it, because its production and processing is more demanding than for maize, sorghum or cassava. Manual weeding of the crop and cleaning of the grains is tedious and time-consuming. Finger millet malt (*kimera*) is used to make *busaa*, an opaque alcoholic beverage (Kirui et al., 2014). The grains can also be exposed to high temperatures by stacking them in heaps when they are still moist. As the grains respire, they produce heat, which raise their temperature to about 80°C. This process changes their colour from red to black (*emifuname*) and improves the colour and taste of *ugali* made from this flour. This product is made in Vihiga, Kakamega and Bungoma counties. This treatment may also improve the nutritional and health properties of the grain. Gahlawat and Sehgal (1994) reported that finger millet subjected to high temperature treatment has improved iron bio-availability, whereas Pushparaj and Urooj (2014) and Pradeep and Guha (2011), noted improved antioxidant activity.

The national per capita consumption of sorghum is 3 kg/person/year (Table 1). More than 75% of sorghum produced in Kenya is used as human food (Table 1). Sorghum is whole milled and composited with maize, finger millet or cassava, which is then used to make *uji* or *ugali*. Most farmers grow tannin-rich sorghum varieties that are bitter-tasting and have poor malting properties. Nonetheless, some malted grain can be used to make *makhalange* or *zimbare* as described earlier. Roasted and milled sorghum is also used as an alternative beverage to caffeine-containing tea and coffee. Roasting sorghum at high temperatures (161 to 179°C) changes its rheological attributes and gives the flour low shear-thinning character, which is ideal for making beverages (Ranganatham et al., 2014). Sorghum rice is made in a similar manner to normal rice by boiling or steaming the dehulled or soaked whole grains until they are soft.

The national per capita consumption of cassava is 24 kg/person/year (Table 1). Almost all cassava (97%) produced in Kenya is used as food (Table 1). Both the bitter and sweet varieties of cassava are grown in the western region of Kenya. The bitter variety is preferred in Busia and Siaya counties because it is high yielding and produces more tubers (8 to 12) per plant than the sweet variety. Sweet cassava varieties are peeled and washed then eaten raw or boiled before eating. They can also be peeled, chipped, sun-dried and milled into flour (*abeta*); or heap-fermented, dried and milled into flour (*akuoga*). Bitter cassava varieties are not eaten raw or after boiling due to their high content of cyanogenic glucosides, which can cause acute toxicity and death (Montagnac et al., 2009b). They must be heap-fermented before they are dried and milled into flour. *Anyonga* is another type of cassava flour, which is made by heap-fermenting cassava roots to make *akuoga*, which is then mixed with *abeta* cassava. The blended chips are once again heap-fermented for 3 days, before they are sundried and milled. *Abeta*, *akouga* or *anyonga* cassava flours are blended with maize, finger millet or sorghum flours and used to make *ugali* or *uji*. Heap fermentation of cassava roots is dominated by moulds (*Rhizopus stolonifer* and *Neurospora sitophila*) and lactic acid bacteria (*Leuconostoc pseudomesenteroides, Leuconostoc mesenteroides, Enterococcus faecium* and *Weissella cibaria*), which decrease the total cyanogenic content and pH; and slightly increase the protein content of the roots (Tivana et al., 2007).

Ugali formulations

Maize, finger millet, sorghum and cassava flours are the main flours used to make *ugali*. The flours are used either singly or as composite flours (Table 2). White semi-dent maize is the most widely used unblended flour for making *ugali*, because the grain is cheap and readily available and has been intensively promoted by the government as the premier national food security crop (Smale and Jayne, 2003). Other popular maize varieties are yellow maize and pigmented maize. Finger millet *ugali* is only made during special occasions, such as wedding ceremonies, because it is almost twice as expensive as the same amount of maize or sorghum. This is because its cultivation and processing is tedious and time-consuming. A special kind of *ugali* (*kuon anang'a)* is made from finger millet and fermented milk, instead of water, and is normally eaten with ghee. Sorghum is the least preferred unblended cereal grain for making *ugali*. It is mainly consumed in poor households, especially during famine, when maize stocks are low. In order to improve the taste of *ugali* made from finger millet or sorghum, the grains are usually roasted before they are milled.

Unblended *abeta, akuoga* or *anyonga* cassava flours are not commonly used to make *ugali* because they give a gummy product. Cassava *ugali* is difficult to form into a ball when it is kneaded in the palm of the hand prior to eating. Furthermore, it has a soft and slippery texture in the mouth, a characteristic that is not associated with normal *ugali*. Despite these negative textural properties of cassava *ugali*, the product is found in Busia and Migori counties where cassava is an important household food security crop. However, even in these counties cassava *ugali* is only made when household reserves of maize, finger millet and sorghum are low or have been exhausted a common occurrence during famine. When a choice has to be made between the kind of cassava product that should be used to make *ugali*, then *akuoga* or *anyonga* cassava are preferred over *abeta* cassava. This is because smaller quantities of the former flours are required to make *ugali*, and the product has better texture. Also, during cooking, it is easier to knead *ugali* made from *akuoga* or *anyonga* than that made from *abeta* cassava. *Ugali* made from *akuoga* or *anyonga* cassava is firmer, less stringy and has better colour, smell and taste than *ugali* made from *abeta* cassava. In terms of taste, the respondents said that *ugali* made from *akuoga* or *anyonga* cassava is sweeter than that made from *abeta* cassava.

Generally, composite flours (Table 2) are preferred over unblended flours for making *ugali* because they have better sensory properties. Cassava (preferably *akuoga* or *anyonga)* flour decreases the firmness and cohesiveness of *ugali* containing cereal flours. On the other hand, the cereals mitigate the gummy texture associated with gelatinized cassava. The types and amounts of flours used to make composite flour is dependent on the desired sensory attributes, cultural practices, and the availability and cost of the raw materials. Finger millet or sorghum grains are commonly roasted before blending with cassava or maize, in order to improve the taste of *ugali*. Sorghum is used in small amounts in most recipes because polyphenols in the grain give the product a bitter and astringent taste, and

Table 2. Major composite flours used to make *ugali* in ten counties in western Kenya.

County	Composite flour	Ratio
Bungoma	Finger millet: cassava	2:1
	Maize: cassava	4:1
	Sorghum: maize (*otwaka*)	1:1
	Cassava: finger millet: sorghum (*saba lulala*)	6:4:1
	Maize: sorghum: cassava	2:2:1
Busia	Cassava: sorghum	6:1
	Cassava: finger millet:	6:1
	Cassava: finger millet: sorghum	10:1:1
	Maize: sorghum: cassava	10:1:4
	Maize: sorghum: cassava	2:1:10
Homa Bay	Maize: sorghum (*kuon cham* or *odongo oher*)	4:1
	Sorghum: cassava	4:1
Kakamega	Finger millet: cassava	2:1
	Maize: sorghum (*otwako*)	3:1
	Maize: cassava	2:1
	Cassava: sorghum	4:1
	Finger millet: sorghum: cassava (*saba lulala*)	4:2:1
Kisii	Finger millet : sorghum	2:1
	Finger millet: sorghum: cassava	2:1:1
Kisumu	Sorghum: finger millet: cassava	2:2:1
	Maize: sorghum: cassava	4:1:1
Migori	Cassava: sorghum	5:1
	Finger millet: cassava	5:1
Nyamira	Finger millet: cassava: sorghum	4:1:1
Siaya	Maize: sorghum	8:1
	Cassava: sorghum	8:1
	Maize: cassava: sorghum	8:4:1
Vihiga	Maize: sorghum (*otama*)	10:1

an intense red-brown colour. Sorghum is also used in small amounts in the composite flour recipes, because it has a high water absorption capacity, which gives dense and compact *ugali*. For instance, *ugali* made from maize and sorghum (*otwako*) in Kakamega County, is liked because the consumer gets satisfied after eating only a very small amount. This recipe is commonly used during famine when poor households cannot afford to eat more than one meal per day. Other recipes that are essential in guaranteeing household food security during lean times are *otwaka* and *otama* in Bungoma and Vihiga counties, respectively; and the 8:1 maize: sorghum recipe in Siaya County.

The *saba lulala* recipe in Kakamega and Bungoma counties, which means ‘eat only once per day’ or ‘wash your hands only once a day to eat’ also aptly shows the association of this recipe with household food security during lean times.

Preparation and quality characteristics of *ugali*

The flour to water ratio required to make *ugali* is about 30% w/v (Onyango, 2014). Water is brought to boil in a cooking pot before adding about 30% flour. Heating is continued without any intervention until boiling resumes. The remaining flour is then added and the gruel is mixed using a flat wooden stick to develop a stiff inelastic, non-flowing paste. Mixing is continued intermittently for the next 7 to 10 min. At the end of cooking, *ugali* should not simmer, which signifies that excess moisture has been driven off. Well-cooked *ugali* should be a single cohesive mass without unhydrated flour particles or lumps of ungelatinized starch (*chimbunda* in Luhya or *chintobe* in Kisii). A hard crispy layer of gelatinized starch remains on the inner surface of the cooking pot. Most *ugali* recipes have a bland starchy taste, neutral pH and slightly burnt aroma. When roasted finger millet or sorghum is used, *ugali* acquires a lightly roasted aroma. *Ugali* made from yellow maize kernels is not popular because it has a distinct strong smell. Poorly-cooked *ugali* has a wet appearance (exudes water), is tasteless, has a gummy texture and sticks in the upper palate of the mouth during chewing. *Kuon anang'a ugali* has a sour taste because it is made with fermented milk instead of water.

The colour of *ugali* is dependent on the colour of flour used to make it. *Ugali* has a white or yellow colour if it is prepared from white or yellow maize kernels, respectively. Whole-milled white maize gives creamish-white non-glossy *ugali*, whereas *ugali* made from dehulled and degermed maize has a bright white colour and glossy appearance. *Ugali* made from pigmented maize kernels is white in colour since the white kernels are dominant in the cob. *Ugali* made from unblended *abeta* cassava has a bright white colour, whereas that made from *akuoga* or *anyonga* cassava has a cream colour. *Ugali* made from cassava and white or yellow maize has a white or yellow colour, respectively. *Ugali* made from unblended finger millet or sorghum or from composite flours containing either of these cereals has a red-brown colour.

Consumers have developed several simple tests to evaluate the texture of *ugali*. The 'wall-test', which is used to know if *ugali* is well-cooked, is done by throwing a piece of *ugali* to a wall. If it sticks on the wall (that is, it is adhesive) it is not well-cooked; if it falls down, it is well-cooked. The texture of *ugali* can also be evaluated by lightly pressing the middle finger into the product. The finger should not puncture or leave a depression in *ugali* that has a firm texture. Well-cooked *ugali* should be moist and have a firm texture that is easy to knead in the palm of the hand into a ball when it is still warm. *Ugali* should not stick on the palm of the hand (that is, should not be adhesive) during kneading into a ball. Poorly cooked *ugali* tends to disintegrate in the hand during kneading and has an adhesive character. *Ugali* should have a mealy, non-adhesive texture in the mouth. *Ugali* made from cereal flours has a rough mouthfeel due to sharp-edged bran and endosperm particles. The texture of this *ugali* is made smoother by incorporating cassava flour in the composite flour. The respondents described poorly cooked *ugali* as being bitter and having a rough texture in the mouth, probably due to ungelatinized starch particles and bran. Objective methods have also been used to evaluate the texture of *ugali*. Onyango (2014) used a Texture Analyser to evaluate the texture of *ugali* and found that the peak force required to cut through a block of maize *ugali* at 55°C ranging from 40 to 80 Newton (N), whereas the total shearing force ranged from 400 to 800 Ns.

Ugali should preferably be consumed when it is still hot, usually within an hour after cooking. Firmness increases whereas the ease of kneading in the hand decreases as *ugali* cools over time due to starch retrogradation. These textural changes make it less appealing and unpalatable after long-term storage. In Kisii and Nyamira counties, staling of *ugali* is delayed by storing it in a traditional hotpot known as *ekee* (calabash-shaped container made from finger millet straw with the lower end covered with cow hide, which acts a sponge to pad on the head during carrying and prevents *ugali* from cooling) and covered with *omonyaboga* leaves, which act like foil paper. Prior to putting *ugali* in the *ekee*, it is sprinkled with flour to reduce adhesion to the container and the leaves. The *ugali* is stuffed tightly and hermetically sealed to prevent any loss of heat. This preservation technique can prolong the shelf-life of *ugali* for up to one week.

Uji formulations

Uji is prepared from unblended or composite flours of maize, finger millet, sorghum or cassava, which may be fermented or unfermented. When making the fermented product, naturally occurring microorganisms, rather than pure cultures, are allowed to develop spontaneously in the slurry. The initial stages of the fermentation are dominated by coliforms and fungi, while lactobacilli are a minor constituent (Masha et al., 1998). As fermentation progresses, contaminant microorganisms are replaced by homofermentative and heterofermentative lactobacilli (Masha et al., 1998). Although lactobacilli are the predominant bacteria, yeasts also play an important role in fermentation by supplying the fastidious lactic acid bacteria with nutrients and degrade raffinose and stachyose (Jespersen, 2003) and impart desirable taste and flavour (Mugula et al., 2003). Commercial processors make chemically-soured *uji* because it is cheaper and less time-consuming. These processors simply add citric acid powder (about 8,000 ppm) to the flours to create the sour taste. Acidulants, such as lemon (*Citrus limon* (L.) Burm. f.) juice extract, tamarind seeds (*Tamarindus*

Table 3. Major composite flours used to make *uji* in ten counties in western Kenya.

County	Composite flour	Ratio
Bungoma	Maize: sorghum	8:1
	Finger millet: maize: cassava	8:1:1
Busia	Finger millet: maize	16:1
Homa Bay	Cassava: finger millet	8:1
Kakamega	Finger millet: sorghum	2:1
	Maize: sorghum	3:1
Kisii	Finger millet: sorghum	2:1
Kisumu	Finger millet: sorghum: cassava	2:1:1
Migori	Cassava: sorghum	10:1
Nyamira	Finger millet: cassava: sorghum	4:1:1
Siaya	Finger millet: cassava	2:1
	Finger millet: cassava: sorghum	8:2:1
Vihiga	Finger millet: sorghum: cassava	4:1:1
	Finger millet: sorghum: cassava: maize	8:1:1:1

indica) or the young shoot of the camel foot plant (*Piliostigma thonningii* (Schum.) Milne-Redh) are also used to make *uji* in several households.

Unroasted finger millet and sorghum are the preferred unblended flours for making *uji*. Unblended maize is only used to make *uji* when finger millet and sorghum are unavailable. The sensory attributes of unblended cassava porridge are poorer than those of cereals. Consequently, unblended cassava is not used to make *uji* (except in Migori County where *anyonga* cassava is used), because the product has bland taste and flavor; and a jelly-like, rather than a free-flowing consistency. Generally, composite flours are preferred over unblended flours for making *uji*, because they give products with better sensory properties. The flour blend used depends on the desired sensory properties. Finger millet is the most preferred grain, whereas maize is the least preferred grain, in composite flours for making *uji* (Table 3). Sorghum is used in small amounts in composite flours because it gives the product a bitter and astringent taste. Cassava (preferably *abeta*) is used in several recipes to give *uji* a smooth texture and decrease grittiness caused by the cereal endosperm and bran particles.

Cereal malt is not used in Kenya as an ingredient in the preparation of *uji*. However, the Kuria in Migori County use finger millet malt to make *togwa. Togwa* is a thin porridge that is widely consumed in Tanzania (Kibatake et al., 2003; Mugula et al., 2003). It is not surprising that the Kuria are aware of this technology since they live along the Kenya-Tanzania border and have acquired this food culture from Tanzania. The Kuria make *Togwa* by adding finger millet malt to cooked *uji,* which is prepared from unblended cassava flour or composite flours of cassava/finger millet/maize; cassava/sorghum/maize; cassava/sorghum; or cassava/maize. The mixture is left to spontaneously ferment for about 8 h before it can be consumed.

Preparation and quality characteristics of *uji*

Fermented *uji* is made by mixing unblended or composite flours with water to obtain liquid slurry (30 to 40 g/100 ml). The slurry is left to spontaneously ferment in a warm place (25 to 35°C) for 24 to 48 h. The pH of the slurry falls from about 6.5 to 4.0 as it develops a sour aroma (Masha et al., 1998). Fermentation is speeded up by using warm water (30 to 35°C) instead of cold water, adding sugar to the slurry, or inoculating the fresh slurry with previously fermented material (back-slop culture). Back-sloping is a highly effective technique for speeding up the natural acidification process because the inoculum is enriched with lactobacilli (Masha et al., 1998). Fermented *uji* has a short shelf-life, usually less than 48 h, and will rapidly deteriorate if it is not cooked and drank immediately. If fermentation is allowed to continue, the product becomes too sour, and could be contaminated with moulds. The shelf-life of the fermented product can be extended by refrigeration or dehydration. The dried flour can be stored at room temperature and reconstituted in water when required. It can also be used as starter culture for the next batch of *uji* slurry that is to be fermented.

Uji is prepared by first bringing a given amount of water to boil. Separately, cold water is mixed with an equal amount of the flour to make a slurry. The cold suspension is added to the boiling water while stirring until a viscous paste is obtained and there is no foaming. The final suspension has flour to water concentration of about 8 to 10% w/v. The suspension is continuously stirred for the first few minutes of cooking to ensure that all the flour gelatinizes and does not clump. Cooking is continued for 10 to 15 min or until the product is smooth and thick. When *uji* is removed from the cooking pot, a thick layer remains at the bottom of the cooking container. The container must be soaked in water for some time to enable this layer to completely dissolve. The same cooking procedure applies to fermented and dried flour, which is first reconstituted in cold water. If the starting point is fermented slurry, it has to be diluted to about 8 to 10% w/v before adding it to the boiling water. For *uji* made from unblended *anyonga,* the dried cassava pieces are first soaked in water then sieved and the filtrate is used to make *uji*.

Uji should have a viscous but free-flowing consistency. Onyango et al. (2004b) found that *uji* made from maize/finger millet, maize/sorghum, cassava/finger millet or cassava/sorghum blends had free-flowing consistencies at viscosities of 1000 to 1500 cP (40°C; shear rate 36 to 64 s^{-1}). In another study Onyango (2014), used a Texture Analyser to evaluate several textural attributes of *uji*. He found that the firmness, consistency, cohesiveness and index of viscosity of maize *uji* ranged between 0.2 and 1.3 N, 6 and 34 N·s, -0.2 and 1.5 N, and -0.3 and 2.1 N·s, respectively. Fermentation does not reduce the viscosity of *uji* (Onyango et al., 2004a; Masha et al., 1998).

The mouth-feel of *uji,* which depends on the particle size of the flours, ranges from coarse and gritty to smooth and creamy. A gritty mouthfeel is due to bran and endosperm particles from coarsely milled cereals. Grittiness can be reduced by milling the flour in successive cycles or using sieves with smaller pores. Generally, sieves with smaller pores are used when milling small grains, such as sorghum and finger millet, while sieves with larger pores are used when milling bigger grains, such as maize. The colour of *uji* largely depends on the colour of finger millet (red or brown) or sorghum (red) used to prepare it. *Uji* made from finger millet is dark brown; that from sorghum and finger millet is red-brown; and that from finger millet and maize is light brown in colour. Poorly cooked *uji* has an uncooked flavour and undergoes syneresis when left to stand. It drains out completely from a cup, whereas well-cooked *uji* leaves a thick layer of the gruel attached to the side of the cup.

Many consumers prefer fermented *uji* over the unfermented product. Unfermented *uji* has a bland, cooked-starchy taste, whereas the fermented product has a pleasant sour taste due to the aroma compounds produced by lactic acid bacteria (Masha et al., 1998). The microorganisms produce enzymes that digest polysaccharides, proteins and lipids in the substrate and produce compounds that contribute to the flavour and aroma. Lactic acid is the main non-volatile aroma compound in fermented *uji,* and is supplemented with other aroma compounds such as branched alcohols, carboxylic acids, esters and aldehydes (Masha et al., 1998; Onyango et al., 2004b). If desired, the sour taste of fermented *uji* can be complemented with sugar to create a sweet-sour flavour.

Other than improving the sensory properties of foods, consumption of fermented foods has several nutritional and health benefits. Fermentation destroys undesirable and harmful compounds in the food, preserves the food, improves its nutritional value and reduces the energy and time required to cook the food (Blandino et al., 2003; Steinkraus, 2002; Hotz and Gibson, 2007). Fermented products are also important sources of lactic acid bacteria with probiotic value. Fermentation improves the safety of foods by producing antimicrobial compounds, produce nutraceuticals with increased bioavailability of nutrients, improve intestinal microbial balance, improve immune system modulation, play a role in management of type II diabetes, and lower serum cholesterol levels (Mokoena et al., 2016; Franz et al., 2014).

***Ugali* and *uji* as functional foods for management of non-communicable diseases**

Kenya among other countries in sub-Saharan African is faced with a tremendous increase in the prevalence of non-communicable diseases such as cardiovascular diseases and type II diabetes (Dalal et al., 2011). Since medications for controlling these conditions are expensive, dietary approaches are more cost-effective. Nutrition epidemiology shows that a diet rich in whole-grain based foods assist in health maintenance and lowers the risk of developing non-communicable diseases. Whole grain foods contains several bioactive substances and phytochemicals that contribute to gut health, increase satiety and help to control body weight (Fardet, 2010; Stefoska-Needham et al., 2015; Saleh et al., 2013; Truswell, 2002). Consumption of high fiber diet slows digestion and retards release of sugar into the blood stream, which improves glycaemic control and reduces the risk of developing non-communicable diseases such as type II diabetes and coronary heart disease (Roberts and Liu, 2009; Hardy et al., 2010). Consumption of millet increases levels of high density lipoprotein in the blood stream and may be useful in managing insulin resistance and cardiovascular disease in type II diabetes (Nishizawa et al., 2009). Furthermore, bioactive compounds in whole grains have anti-oxidant and anti-inflammatory properties that suppress tumors and have anti-carcinogenic properties (Fardet, 2010; Stefoska-Needham et al., 2015; Saleh et al., 2013; Awika and Rooney, 2004; Truswell, 2002).

In this study, the researchers reported that whole-milled maize, finger millet and sorghum grains are recommended for making *ugali* and *uji* for people suffering from cardiovascular diseases and type II diabetes. Mlotha et al. (2016) studied the glycemic index of a thick porridge (*nsima*) in Malawi, which is similar to *ugali*, and found that *nsima* prepared from fermented maize grits has a lower glycemic index than that prepared from whole maize flour or unfermented maize grits. They recommended that fermented flours should be used to prepare maize-based foods for diabetics. By contrast, cassava is not recommended in food recipes for diabetics because it is rich in rapidly digestible starch (Yessoufou et al., 2006), which can cause a sudden spike in blood sugar levels. However, cassava starch digestibility can be decreased by converting it into resistant starch (Lertwanawatana et al., 2015), and hence it is possible to develop cassava-based nutritional products for the management of non-communicable diseases.

Uji as a complementary food for children

Unfermented *uji* is an important food for complementary feeding of children (children are not fed fermented *uji* because they are unfamiliar with the sour taste and hence consume very small amounts). However, because only a small amount of flour (less than 10% w/v) is required to make the product, it has a low energy density (0.3 kcal/g) (Onyango et al., 2004a), which is below the minimum recommended energy density of thin porridge (0.8 kcal/g) for complementary feeding (WHO/UNICEF, 1998). Consequently, children weaned exclusively on un-supplemented thin porridge have inadequate energy intake and suffer from energy malnutrition (Kulwa et al., 2015). Furthermore, the overall inadequate nutrient intake exposes children to other dietary-related illnesses, such as stunting and wasting (Kulwa et al., 2015).

Simply increasing the flour concentration in order to increase the energy density of porridge for child-feeding is not effective because the product will be too thick and a child will find it difficult to chew and swallow (Onyango et al., 2004a). The energy-density of thin porridges for complementary feeding can be increased by adding amylase-rich malt flours (Thaoge et al., 2003) or microbial amylases (Onyango et al., 2004a) to the slurries. The amylases hydrolyse starch to maltose and low molecular weight dextrins, which have low water binding capacities, do not gelatinise when cooked and produce low viscosity porridges with potentially high energy densities provided the recommended amount of flour is used (Onyango et al., 2004a). Thaoge et al. (2003) showed that sorghum malt flour (5%) can be used to make thin porridge (2,500 to 3,000 cP) with a high (30% w/v) solids content. Microbial amylase can also be used to increase the amount of flour required to make *uji* (20% w/v) and obtain a product with a high energy density (2.51 to 3.35 kJ/g) and appropriate viscosity 1000 to 2000 mPa.s (Onyango et al., 2004a). Despite widespread academic knowledge on the positive influence of malt on the energy density of porridge, this technology has not been adopted in Kenya, except by the Kuria in Migori County, who use malt flour to make *togwa*.

Maize, finger millet, sorghum and cassava are good sources of dietary energy because of their high carbohydrate content. The carbohydrate content in cereals is about 75% (Mckevith, 2004) and in cassava is 80 to 90% on dry-weight-basis (Montagnac et al., 2009a). However, these foods have low protein contents. The protein content of cereals is about 6 to 15% (Mckevith, 2004), whereas cassava roots have 1 to 3% (Montagnac et al., 2009b). Cereals are deficient in lysine and tryptophan but are rich in cysteine and methionine (Mckevith, 2004). Cassava root is deficient in methionine, cysteine and tryptophan (Montagnac et al., 2009a). Many respondents said that they improve the quality and content of protein in *uji* for complementary feeding with legumes (Table 4), such as soybean (*Glycine max* (L.) Merr), amaranth (*Amaranthus cruentus* L.), common bean (*Phaseolus vulgaris* L.), groundnuts (*Arachis hypogaea* L.) or sesame (*Sesamum indicum DC*). Legumes are rich in lysine but are deficient in sulphur containing amino acids (Blandino et al., 2003). Hence, supplementing cereal/cassava porridges with legumes improves the content and quality of proteins in the porridges (Ejigui et al., 2007; Anyango et al., 2010; Muoki, 2013). The bioavailability of nutrients in plant foods can be further improved by other pretreatments, such as soaking, germination, fermentation and thermal treatment, which reduce the levels of anti-nutrients, improve mineral absorption and reduce the incidence of common infections in children (Gibson et al., 2006). Animal proteins such as milk or silver cyprinid

Table 4. Major composite flours used to make *uji* for complementary feeding of children in ten counties in western Kenya.

County	Composite flour mixture	Ratio
Bungoma	Finger millet: soybeans: groundnuts: common bean	16:8:2:1
	Sorghum: finger millet: soybeans: groundnuts: beans: silver cyprinid	2:2:1:1:1:1
Busia	Finger millet: maize: soybeans: groundnuts: beans: cassava: amaranth: silver cyprinid	32:4:1:1:1:1:1:1
Homa Bay	Cassava: finger millet	8:1
Kakamega	Maize: groundnuts: soybeans	32:1:1
	Finger millet: groundnuts: soybeans	32:1:1
	Finger millet: maize: groundnuts: soybeans	8:4:1:1
Kisii	Finger millet: groundnuts: beans: soybeans: green bananas: silver cyprinid	4:1:1:1:1:1
Kisumu	Finger millet: sorghum: groundnuts: soybeans: simsim: amaranthus: green gram	4:1:1:1:1:1:1
Migori	Cassava: sorghum: beans: groundnuts	8:2:1:1
	Finger millet: soybeans: groundnuts: silver cyprinid	4:1:1:1
Nyamira	Finger millet: sorghum: soybeans: groundnuts: cassava	4:1:1:1:1
Siaya	Finger millet: groundnuts: soybeans: sorghum: cassava	4:1:1:1:1
Vihiga	Finger millet: sorghum: cassava: groundnuts (or soybeans)	4:1:1:1

(*Rastrineobola argentea;* locally known as *omena* or *dagaa*) may also be used to improve the content and quality of protein in *uji*.

The choice of protein material used to improve the nutritional quality of *uji* for complementary feeding is determined by several factors such as affordability, sensory properties and its functional properties. Milk is not commonly used because it is expensive. Undesirable sensory properties of foods may limit the energy and nutrient intake of the food by children. Silver cyprinid is used in small amounts because it gives *uji* a distinct off-flavour that is unappealing to children. Acceptability of cereal porridges blended with high contents of legumes may be limited due to the beany flavour (Asma et al., 2006; Obatolu et al., 2000). Mosha and Bennink (2005) found that *uji* made from extruded corn-bean-sardine meal or sorghum-bean-sardine meal had better texture, colour and taste relative to *uji* made from maize meal. In terms of product functionality, Anyango et al. (2011) showed that addition of cowpea to sorghum decreases the peak viscosity and cool paste viscosity of *uji*. They attributed the textural changes to the increase in protein content and the concomitant decrease in starch content in flour as a result of cowpea addition.

Conclusion

Maize, finger millet, cassava and sorghum are the basic raw materials for the production of thick (*ugali)* and thin *(uji)* porridges in Kenya. The flours are used either singly or as composites. *Ugali* is principally eaten for lunch or dinner as the main meal whereas *uji* is consumed as a refreshing drink any time of the day. The flours can also formulated to meet the nutrient requirements of special categories of consumers such as children, invalids and people suffering from non-communicable diseases. The nutritional quality of *uji* for child-feeding is improved by adding plant or animal proteins. People suffering from non-communicable diseases are fed ugali and uji made from whole-milled cereal flours. The products are largely made at home and hence product quality is extremely diverse. Several opportunities exist to improve the quality and safety of these products. Cereal malt could be utilized to improve the energy density of *uji.* The products could be made into ready-to-eat porridges that require little energy and time to prepare at home. Opportunities for further product development and commercialization of novel products such as gluten-free African bread (*estata*), *makhalange* (*zimbare*), *emifuname*, sorghum rice, and caffeine-free sorghum beverage also exist. Microbial strains with unique technological and functional properties could be identified in *uji* and *togwa* and used to develop probiotic foods. Finally, industrial production of these porridges based on scientific principles and in commercial quantities can contribute to improved food and nutrition security in the country.

Conflict of interests

The authors have not declared any conflict of interests.

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