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Crop ash filtrate influence on cooking time and sensory preferences for dried black beans (*Phaseolus vulgaris* L.)

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Filtrate made from the burnt ash of crop plant residue is used in cooking in Northern Uganda. This practice is believed to decrease the cooking time of hard-to-cook legumes and provide a culturally preferred taste. The objectives of this study were to: (1) compare cooking times and sensory preferences for dried black beans (*Phaseolus vulgaris* L.) among four treatments: plain water (control), table salt, crude ground salt, and ash filtrate; and (2) determine demographic factors (gender, age, and education) that may also influence preferences. Sensory preferences for beans cooked across the treatments were evaluated through blind taste tests. Analysis of variance (ANOVA) with post-hoc Bonferroni multiple comparisons showed a statistically significant ($p < 0.01$) 27% reduction in cooking time with the addition of ground salt and 18% shorter cook time with ash filtrate. Contrary to anecdotal belief, participants showed an overall preference for black beans cooked with ground salt and table salt over plain beans or those cooked with ash filtrate. The type of treatment and study site significantly ($p<0.05$) impacted sensory scores. Demographic factors did not influence sensory preferences within or between communities, suggesting that cultural preference for the use of ash filtrate is being influenced by more than actual taste. The reduction in cooking time has important implications for fuel wood requirements as the majority of households rely on fires for cooking.

Key words: *Phaseolus vulgaris*, crop ash filtrate, cooking time, sensory characteristics, Northern Uganda.

INTRODUCTION

Legumes are one of the best sources of vegetable protein available in developing countries (Siegel and Fawcett, 1976) and are a staple food in Uganda (Mamiro et al., 2011). Black beans (*Phaseolus vulgaris*) are particularly common in Northern Uganda, as both a domestic crop and commercial product in markets. The typical climate of Uganda, humid and moderately hot (20-30°C), creates poor storage conditions for legumes (Reyes-Moreno and Paredes-Lopez, 1993). Drying and storage in these conditions result in beans becoming

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hard-to-cook; a property which requires extensive cooking time to make them palatable, eliminate toxic components, and allow for the protein to become nutritionally available (Varriano-Marston and de Omana, 1979; de León et al., 1992). Salt is regularly used to decrease the cooking time of dried, hard-to-cook legumes (Uzogara et al., 1990; Onwuka and Okala, 2003; Mamiro et al., 2011). Depending on availability, people of different regions use several different types of salt or salt-like additives for cooking. These may include refined commercial (table) salt (NaCl), a crude indigenous (ground) salt precipitated from saline lakes, and/or the ash of plant parts.

The cooking of legumes involves several processes to render them palatable, digestible, and accessible to nutrient availability. A main component of plant cell wall structure includes pectic substances, which need to be degraded in order for internal cell tissue, and therefore the bean, to soften (Uzogara et al., 1990). Commercial (table) salt decreases cooking time for legumes by accelerating the degradation of this pectin (Van Buren, 1986), through ion exchange and chelation where ions of the ‘intercellular cement’ are either replaced by sodium ions or leached out (Varriano-Marston and Omana, 1979). In some parts of the world, an indigenous ground salt is also used to speed up cooking time of legumes. Ground salt is composed mainly of trona, a hydrated sesquicarbonate of sodium, which makes it highly alkaline (Makanjuola and Beetlestone, 1975). Alkalinity has been shown to have great influence on the softening of legumes, probably due to an effect on the starch gelatinization process (Wanjekeche et al., 2003) and in turn, decreases the necessary cooking time (Ankrah and Dovlo, 1978; Uzogara et al., 1990; Onwuka and Okala, 2003). As an alternative to ground salt, plant ash and/or plant ash filtrate is used as a traditional cooking additive in some areas of the world, including rural Africa (Kaputo, 1996; Wanjekeche et al., 2003; Mamiro et al., 2011). Plant ash and ground salt are both highly alkaline, and have been shown to have elevated mineral content; both factors which probably contribute to the observed reduced cooking time. Previous research has found no significant difference in the cooking time of beans when either plant ash or ground salt have been added (Mamiro et al., 2011).

In rural Northern Uganda, there is anecdotal information that a filtrate made from residual crop ash also considerably reduces the length of time required to cook dried legumes. The plants most often burnt for ash are crop residues of legumes, and sesame (*Sesamum indicum*). While there is ample information on the use of sodium salts to hasten the cooking of legumes, research on the use of crop ash and filtrate as an additive is limited. Further, there have been no simultaneous direct comparisons of the effect of all three types of salt additives on the cooking time of legumes.

Table salt (NaCl) is also frequently added to a variety of foods to enhance taste and sensory preference, and to speed cooking. During cooking in Northern Uganda, people may add to their food a combination of commercial table salt and ground salt (precipitate from saline lakes) or plant ash filtrate to infuse a distinct culturally-preferred flavour. In particular, these cooking additives are used with hard-to-cook legumes, which benefit from both time saving and improved taste. While subjective and possibly culturally/geographically dependent, sensory acceptability is key to understanding important reasons for either the use or disuse of specific additives in cooking legumes.

Sensory evaluation for cooked legumes has previously included colour, taste, texture, and overall acceptability (Silva et al., 1981; Onayemi et al., 1986; Onwuka and Okala, 2003). However, relatively few studies have focused on the use of traditional salts in cooking legumes, and even fewer have included sensory evaluation as a component of the study. Comparison of fresh mucuna beans (*Mucuna pruriens*) cooked with ground salt, citric acid, and plant (maize cob) ash showed preference for the texture of beans cooked with ash and the taste of beans cooked with the ground salt (Wanjekeche et al., 2003). Interestingly, taste scores were significantly higher for beans cooked with ground salt (Wanjekeche et al., 2003), despite the fact that these two additives share many common properties (Mamiro et al., 2011). The colour of both treatments was unacceptable to panelists; a result commonly found with alkaline treatments. Onwuka and Okala (2003) looked at four parameters of palatability for different cooking treatments, including plain water, ground salt (*akanwa*), table salt, and two mixed salts ($NaHCO_3$ and $CaCl_2$). With respect to the first three treatments, respondents rated the legumes cooked with table salt as the most desirable across all parameters, while the legumes cooked with *akanwa* were deemed least acceptable. The colour of beans cooked with *akanwa* was too dark and the flavour less palatable than either the control or beans cooked with table salt and only the texture of the *akanwa* beans was comparable to the other samples. Onayemi et al. (1986) also found poor acceptability for cowpeas cooked in either local rock salt (ground salt) or alkali potash (sodium carbonate; functionally similar to plant ash). Prior research using sensory evaluation tests have shown that traditional salts are not preferred, despite a strong cultural presence and continued use. Further, over addition of these salts contributes to a sharp, unpleasant taste (Onayemi et al., 1986), possibly due to the high alkalinity. For this reason, bitterness was added as a parameter in this study.

Within these few studies, analysis of sensory preference for common black beans (a staple legume in Uganda) cooked with ash filtrate or ground salt has not been conducted. Also undocumented is the assessment of whether demographic factors (gender, age, and education) may influence preferences.

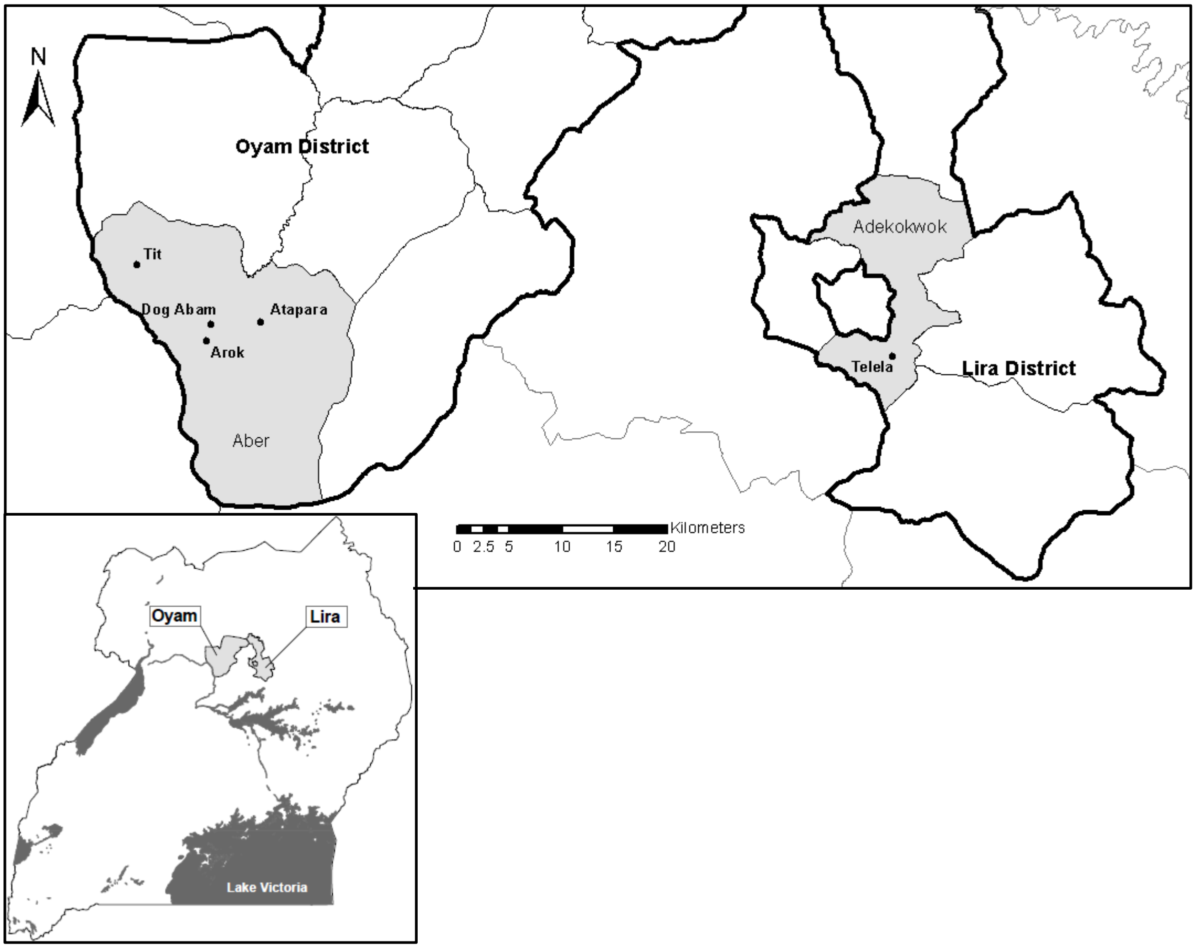

Figure 1. Map of study sites (Dog Abam, Arok, Tit and Telela villages). The primary researcher (first author) was based at Atapara Village.

The objectives of this study were to: (1) compare the time required to cook dried black beans in four treatments: Type 1 water (control) (Ultrapure water filtered with a Millipore® system meeting ASTM® standards for Type 1 water), ground salt, table salt and ash filtrate; (2) determine if beans cooked with ash filtrate are preferred over those cooked in plain water, commercial salt or ground salt; and (3) examine whether demographic factors such as gender, age, or education level influence taste preferences. It was hypothesized that all treatments would decrease cooking time, when compared to the control. It was also hypothesized that beans cooked with the ash filtrate would be the most preferred treatment, and that the demographic factors would influence overall sensory preferences.

Description of the study sites

The field-based part of this study took place in Northern Uganda. The study involved three villages (Dog Abam, Tit, and Arok) in Oyam District, and Telela Village in Lira District (Figure 1). The choice of study sites was based on previous interaction between a non-governmental organization, the Northern Uganda Development Foundation (NUDF), and local community members. NUDF is a Canadian-based organization with field operations in Northern Uganda. Given the cultural and linguistic challenges, utilizing study sites with established relations to NUDF provided a base from which to begin to ensure a timely method of study. The study sites are characterized by poverty, poor infrastructure, traditions and rituals. The laboratory-based (controlled cooking trials) part of the study took place at the University of Northern British Columbia (UNBC) in Prince George, British Columbia, Canada.

MATERIALS AND METHODS

Observation period

A total of two months, from June to August 2012 were spent in the villages chosen for the study. The first month (the orientation period) was spent on observing local culture and customs. An effort was made to become familiar with the local staff of NUDF and members of the village communities. Developing relationships with individuals and establishing trust among the villagers was considered an important function of the observation (Pratt and Loizos, 1992). Prior to data collection, a meeting was held with the local research assistant/translator to explain the process and goals of this study, answer any questions, and ensure privacy for all participants through a signed confidentiality agreement. All research methods, including UNBC's Research Ethics Board approval for the study, were discussed with the staff of NUDF and the villagers before implementation.

Qualitative data collection

Many people in the villages in the study area are illiterate and therefore oral research methods (Le Roux, 1998) were used to gain a comprehensive understanding of cooking food using ash filtrate in the region. Video and photo documentation of ash and ash filtrate procurement procedures (from crop harvest through use in cooking) were also used in the study.

Informal semi-structured interviews

Informal semi-structured interviews (Sammy and Opio, 2005) were used in this study to obtain the opinions of the people in the study area about the use of ash filtrate for cooking food in the region. These methods were chosen because of their flexibility in design and implementation (Mikkelsen, 1995). Individual and group interviews were conducted spontaneously whenever an opportunity arose. Informal conversations were also conducted (Pratt and Loizos, 1992; Devereux and Hoddinott, 1993; Stake, 1995; Chambers, 1997). Most village interviews, even if initially conducted with individuals, developed into group interviews. These proved to be more socially acceptable, stimulated greater discussion and generated more information about the use of ash filtrate in the region (Sammy and Opio, 2005).

Preparation of samples for sensory evaluation

The study consisted of four cooking treatments for black beans (*P. vulgaris L.*). Four 240 g samples of dried black beans were sorted by hand and shriveled beans and other detritus were removed. Large aluminum pots were thoroughly washed three times prior to use and rinsed with distilled water. Pots were then prepared with the beans, 2.0 L of distilled water and one of four treatments; plain distilled water – 'control'; water with 5 g of commercial iodized salt – 'table salt', water with 5 g of ground salt – 'ground salt', and water with 45 ml (3 tablespoons) of plant ash filtrate – 'ash filtrate'. The ash filtrate used for this portion of the study was prepared at the Dog Abam site by a local woman and was documented by photo and video. The steps involved in creating ash filtrate included: (1) harvesting leguminous plants and allowing them to dry under the direct heat from the sun; (2) thrashing the plants to release seeds from pods; (3) burning piles of spent plant remains, including leaves and roots; (4) collecting the ash; (5) ripping spear grass (*Pennisetum purpureum*) into soluble length to cover the bottom of a cup with 0.5 cm holes at the bottom; (6) placing 250 g of the ash onto the spear grass filter bed; (7) wetting the loose ash with a small amount of water and pressing into a filter bed; and (8) allowing approximately 200 ml of water to percolate through the ash and collecting it into another cup as filtrate.

The amount of water required for cooking and the treatment concentration was determined by consulting with several women in the region. Women are responsible for all cooking related activities for the household including collection of firewood and water. These concentrations of table salt (0.25% w/v), ground salt (0.25% w/v), and ash filtrate (2.25% v/v) were also comparable with similar studies (Onayemi et al., 1986; Wanjekeche et al., 2003).

Local charcoal stoves were used due to lack of electricity in the region, as well as to replicate typical cooking conditions. Following the traditional cooking methods and learning how to use local equipment, provided an understanding of the time and energy required for the food preparation done daily by local women. Additional distilled water was added as necessary throughout cooking as follows: plain (control) 1.5 L, table salt 1.5 L, ground salt 1 L, and ash filtrate 1 L. Beans were tested for completion of cooking by hand and mouth feel by the first author and a local woman employed at Pope Paul Hospital, Atapara (Figure 1) who regularly cooks black beans. This method has been previously used for similar tests (Ankrah and Dovlo, 1978; Onwuka and Okala, 2003; Wanjekeche et al., 2003). Once drained and cooled, each pot of beans was divided into four separate airtight plastic containers for individual use at each site. Each lid was labeled with a code letter and number describing treatment sample and intended site. Samples were refrigerated immediately at Atapara Hospital storage refrigerator and all sensory evaluations took place within 36 h.

Sensory evaluation

The sensory rating form, which had been developed prior to conducting the field study, was pre-tested to clarify and assess appropriateness of the form, determine the length of interviews and gain familiarity in working with the research assistant.

The form was completed by 12 people at each of 4 study sites for a total of 48 participants. Participants were chosen by availability and willingness. Random selection of participants was not an option, given logistical and time constraints and lack of sampling frame. There were an equal number of men and women at each site, ranging in age from 18 to 79 years old. Each participant regularly consumed beans prepared with filtrate and so was familiar with the practice of using filtrate for cooking. Signed consent forms were obtained from each person, with an explanation of activities described to them by the research assistant/translator.

Each participant answered questions regarding their demographic status, including age, gender, and education level. At each site, a random number draw dictated the order of placement for samples to minimize potential order bias and lids were placed underneath the sample containers to hide the descriptive code from both the participant and research assistant. Evaluations were conducted in private via translation. Samples were provided to each participant, in each village studied, by disposable spoon, at ambient temperature. Each treatment was tested using a 5-point Likert type scale for sensory properties of smell, colour, flavour, texture, bitterness (chalkiness), and overall acceptability of beans. Texture was measured on two accounts; both for hardness, from too hard (1) to good (5) and for softness, from too soft (1) to good (5), in order to identify beans which were both deemed to be either under or over-cooked. The scale and categories were adapted from previous successful methodologies (Silva et al., 1981; Onayemi et al., 1986; Onwuka and Okala, 2003).

Quantitative data collection on cooking time

This part of the study took place at UNBC, from September to October 2012. The study consisted of four cooking treatments for black beans (*Phaseolus vulgaris* L.) (Type 1 water – 'control', water containing commercial salt – 'table salt', water containing local ground salt – 'ground salt', and water containing plant ash filtrate – 'filtrate'). Dried black beans were sorted by hand, and shriveled beans and other detritus were removed. Four 2.3 L Starfrit Starbasix® saucepans were thoroughly washed three times prior to use, rinsed with Type 1 water, and dried. They were then prepared with 80 g of dried beans, 1.0 L of Type 1 water, and one of the four treatments. For 80 g of dried beans, the following amounts were used: 2 g of commercial salt, 2 g of ground salt, and 15 ml of ash filtrate. These concentrations of table salt (0.2% w/v), ground salt (0.2% w/v), and ash filtrate (1.5% v/v) are comparable with similar studies (Onayemi et al., 1986; Wanjekeche et al., 2003). Approximately 250 g of loose, dry ash was placed into an unbleached coffee filter. The filter with ash was placed into a perforated (0.5 cm holes at the bottom) plastic cup. A small portion of 200 ml of Type 1 water was added to the ash which was slightly tamped down to form a filter bed. The remainder of the water was slowly added and percolated through, collecting in another plastic cup for use. The Dog Abam ash sample was used for preparing filtrate for the study.

The beans were cooked individually on four separate Toastess® cooking ranges (THP432). Each cooking range was preheated to maximum temperature (550°C), as indicated by the automatic shut off switch, and covered pots were placed simultaneously at the maximum temperature. The pH of cooking water of each treatment was taken using a Bluelab® pH pen immediately after mixing in the respective additive to the cooking water; just prior to placing pots on burners. Values of pH were recorded for each treatment once the reading held steady for 10 seconds, and the pH pen was rinsed in Type 1 water prior to subsequent test. Temperatures of prepared pots were identical at the time of placement, and were recorded at time of boiling and time of completion using individual UEi™ DT15A Digital Thermometers. Beans were considered cooked and the time recorded when puncture force registered as 150 g (Silva et al., 1981), as measured with a Mecmesin gram gauge DGD-6. Beans continued cooking until considered soft by hand and mouth feel (Ankrah and Dovlo, 1978; Onwuka and Okala, 2003; Wanjekeche et al., 2003); and where beans easily ruptured between fingers and had attained a consistent softness, and time was recorded again. This was done for comparative purposes, as the consistency of beans considered cooked at 150 g of puncture force was still chalky, and not palatable according to preference standards observed in Uganda. This cooking time trial procedure was repeated three times for replication purposes.

Data analysis

Cooking time data were tested for normality using the skewness and kurtosis test, and all variables met the assumptions of normality. Homogeneity of variance was confirmed by Levene's statistic. Post-hoc Bonfferoni multiple comparison tests were used to determine significant differences among treatment means (Gotelli and Ellison, 2004). The conservative nature of using a Bonfferoni test ensured significantly different cooking times as applicable to actual situations where at least a moderate time difference would be required to have noticeable implications for cooking time. Statistical significance was determined with $\alpha = 0.05$ and the null hypothesis was that no difference existed among means between control and treatments.

Analysis of variance (ANOVA) tests were used to assess significant differences among means of response variables associated with cooking treatment. The mathematical model used was:

$$Y_i = \mu + treatment_i + \varepsilon_i \qquad 1$$

where Y_i = response variable mean (pH, temperature of cooking water treatment at boiling, temperature of cooking water treatment at 15 minutes, cooking time to 150 g puncture force test, or cooking time to palatable); μ = grand mean response variable; $treatment_i$ = cooking water treatment (Type 1 water [control], commercial salt, ground salt, ash filtrate); and ε_i = experimental error.

Statistical analysis was done using Stata® (Version 12). Compilation of interview responses and determination of percent responses were completed using Microsoft® Excel 2010.

The sensory preference data were collected under the assumption of approximating interval level data (Norman, 2010) for analysis with parametric statistical testing. The data did not meet assumptions of normal distribution and primary analysis of treatment means was done through non-parametric measures. Kruskal-Wallis rank tests were performed among treatments with built in post-hoc multiple comparisons to distinguish differing treatments.

Two-factor ANOVA tests were run to further examine whether the site or demographic factors (gender, age, and education level) contributed to the treatment effect on overall acceptability of beans. Despite not meeting assumptions of normality, the ANOVA tests were run under the assumption that data would approximate normal as per the central limit theorem (n = 48). Test for statistical significance of the data was set at $\alpha = 0.05$.

The mathematical model used for the two-factor ANOVA between site and treatment was:

$$Y_{ij} = \mu + site_i + treatment_j + (site \times treatment)_{ij} + \varepsilon_{ij} \qquad 2$$

where Y_{ij} = preference (rating for overall acceptability) mean; μ = grand mean preference; $site_i$ = study site (Dog Abam, Telela, Arok, Tit); $treatment_j$ = cooking water treatment (distilled water [control], commercial salt, ground salt, ash filtrate); $(site \times treatment)_{ij}$ = interaction between site and treatment; and ε_{ii} = experimental error. The null hypotheses were that there was no difference in means of site, there was no difference in means of treatment, and there was no interaction between site and treatment.

The mathematical models used for the two-factor ANOVAs between demographic factors and treatments were:

$$Y_{ij} = \mu + factor_i + treatment_j + (factor \times treatment)_{ij} + \varepsilon_{ij} \qquad 3$$

where Y_{ij} = preference (rating for overall acceptability) mean; μ = grand mean preference; $factor_i$ = demographic factor of either gender, age, or education level; $treatment_j$ = cooking water treatment (distilled water [control], commercial salt, ground salt, ash filtrate); $(factor \times treatment)_{ij}$ = interaction between demographic factor and cooking water treatment; and ε_{ii} = experimental error. The null hypotheses were that there was no difference in means of any factor (gender, age, or education level), there was no difference in means of treatment, and there was no interaction between the factor (gender, age, or education level) and treatment.

The analysis was completed using the Stata® (Version 12) software package. Compilation of interview responses and determination of percent responses were completed using Microsoft® Excel 2010.

RESULTS AND DISCUSSION

Properties of beans cooked with water only, table salt, ground salt, and ash filtrate

Differences among treatment solutions are presented in Table 1. Cooking water pH levels were significantly ($p < 0.05$) different among all treatments, with ground salt (9.6 ± 0.06) and ash filtrate (10.5 ± 0.03) being the most alkaline. The temperature of cooking water, both at time of boiling and the average throughout cooking, did not differ significantly ($p > 0.05$) among treatments. However,

Table 1. Mean (± standard error) treatment values of pH, temperature, time to boil and cooking times (n = 3). Values along rows with the same superscript are not significantly different at p≥ 0.01 by the Bonferroni method.

Parameter	Treatment			
	Control	Table Salt	Ground Salt	Ash Filtrate
pH of cooking treatment	7.7* ± 0.07[a]	8.2 ± 0.03[b]	9.6 ± 0.06[c]	10.5 ± 0.03[d]
Temperature at boiling (°C)	97.6 ± 0.19[a]	97.5 ± 0.13[a]	97.6 ± 0.13[a]	97.6 ± 0.09[a]
Temperature at 15 min (°C)	97.8 ± 0.07[a]	97.9 ± 0.06[a]	97.7 ± 0.09[a]	97.6 ± 0.07[a]
Time to boil (minutes)	9.78 ± 0.06[a]	9.21 ± 0.32[ab]	8.37 ± 0.27[b]	9.37 ± 0.29[ab]
Cooking time to 150 g puncture force (min)	101.0 ± 0.88[a]	101.3 ± 0.88[a]	82.7** ± 0.88[b]	88.3 ± 0.67[c]
Cooking time to eating soft (minutes)	113.0 ± 1.15[a]	121.7 ± 1.20[b]	82.7** ± 0.88[c]	92.7 ± 1.20[d]

*pH analysis of pure Type 1 water may not yield accurate results due to lack of elements and conductivity in the water.
**The texture of beans cooked in the ground salt treatment was deemed satisfactory according to Ugandan preferences at the time of puncture force test, demonstrated by the same value for both of the cooking times. This texture was used as a comparative threshold for other treatments.

Table 2. Chi-squared value, corrected for ties, (x^2, 3 d.f.) and rank mean scores for treatments (n=48). Values along rows with the same superscript are not significantly different at p≥ 0.004167 (Bonferroni like adjustment).

Characteristic	x^2	Treatment			
		Control	Table Salt	Ground Salt	Ash Filtrate
Smell	18.13 (p<0.001)	77.13[a]	107.00[ab]	117.98[b]	83.90[a]
Colour	12.04 (p=0.007)	79.09[a]	106.03[ab]	111.18[b]	89.70[ab]
Flavour	27.55 (p<0.001)	70.61[a]	116.30[b]	116.83[b]	82.25[a]
Texture (hardness)	33.60 (p<0.001)	58.91[a]	107.35[b]	119.28[b]	100.46[b]
Texture (softness)	29.38 (p<0.001)	61.65[a]	106.68[b]	116.45[b]	101.23[b]
Bitterness	12.10 (p=0.007)	88.09[ab]	102.52[ab]	115.18[a]	80.21[b]
Overall	31.41 (p<0.001)	68.80[a]	112.44[b]	122.74[b]	82.02[a]

despite similar temperature, a statistically significant difference among means was found for the time to boil but only between the control (9.78 ± 0.06[a] min) and ground salt treatments (8.37 ± 0.27[b] minutes). A significant difference among means was found for cooking time necessary to obtain a puncture force of 150 g. The addition of ground salt significantly (p ≤ 0.01) decreased time by up to 18% and ash filtrate by up to 13%, compared to either the control or table salt treatments. The required cooking time to acceptable texture increased for all treatments except ground salt, which felt palatable and not at all chalky when the puncture force test was passed. A significant (p≤ 0.05) difference among treatment means was found for cooking time to acceptable texture. The ground salt and ash filtrate treatments decreased cooking time to eating soft significantly (p ≤ 0.01), compared to the control, by 30.3 and 20.3 min or 27 and 18%, respectively.

Sensory properties of beans cooked with water only, table salt, ground salt, and ash filtrate

A non-parametric chi-square analysis showed treatment effects on all sensory characteristics (Table 2). Higher values demonstrate a greater preference for the treatment. There is a distinct preferential pattern for beans cooked with the ground salt across all parameters, followed by beans from the table salt, then beans from the ash filtrate, and least preferred were those cooked in the plain distilled water (control) (Figure 2). The only anomaly in the rankings was that beans cooked in the ash filtrate scored lowest for bitterness.

Several two-factor ANOVAs were used to identify possible interactions between study site, treatment, and three demographic factors (age, gender, and education level). The results revealed a significant (p<0.05) main effect of both treatment and study site on overall sensory preference, suggesting cultural taste variation on a small geographic scale. There was also a significant interaction between the two factors, with specific differences evident at the Arok site, where the table salt treatment was not well accepted (Figure 3). Otherwise, the general trend of taste preferences supported Kruskal-Wallis results for overall preference scores. Further, independent variables investigated with cooking treatment through two-factor ANOVA included factors of gender, age, and education level. There was no main effect of gender, age, or

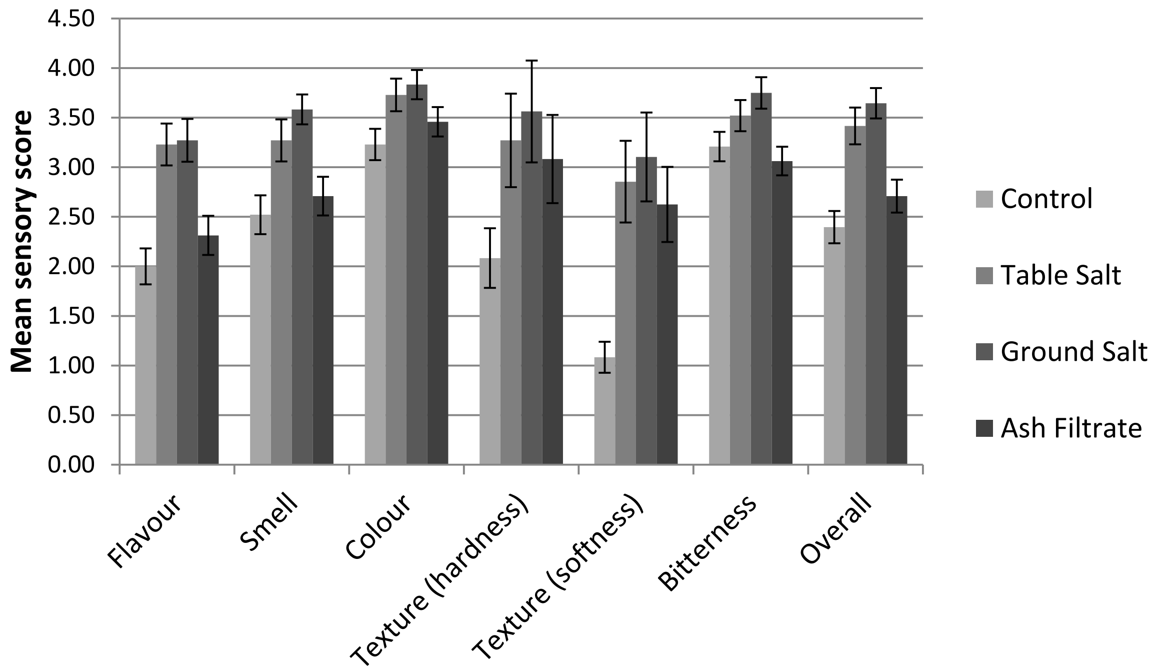

Figure 2. Mean (± standard error) scores of sensory preference by parameter for treatments.

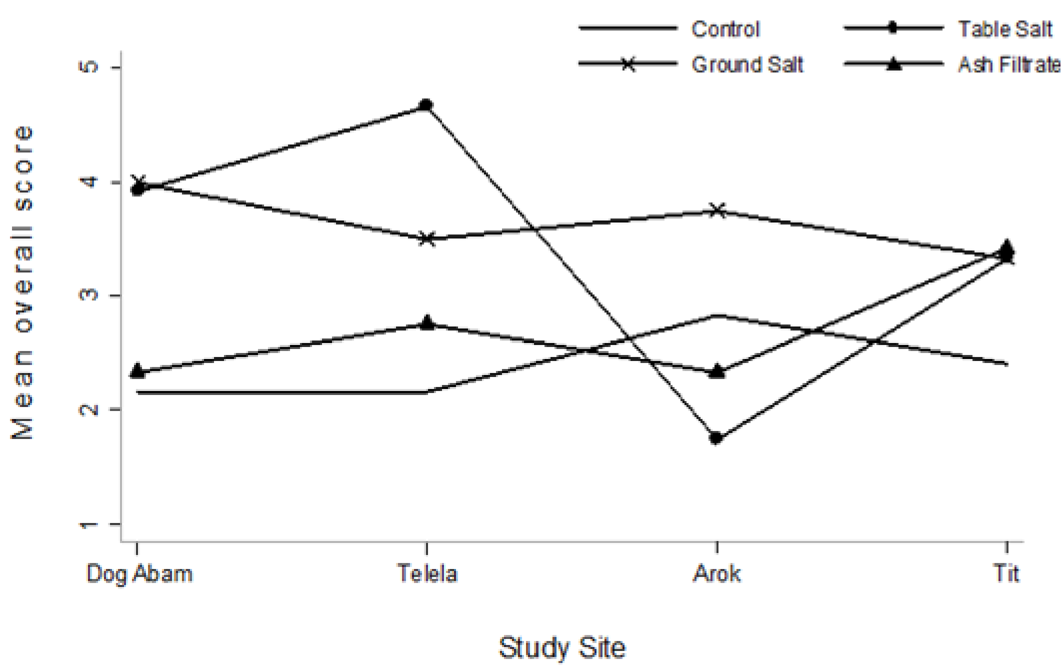

Figure 3. Interaction terms between study site and treatment type on respondents' overall sensory scores.

education level; however, the treatment type was a significant ($p<0.05$) main effect in each test. There were no interactions between treatment and gender, age, or education level.

Participant responses to cooking times and sensory characteristics

Statistical findings supported interview responses, where

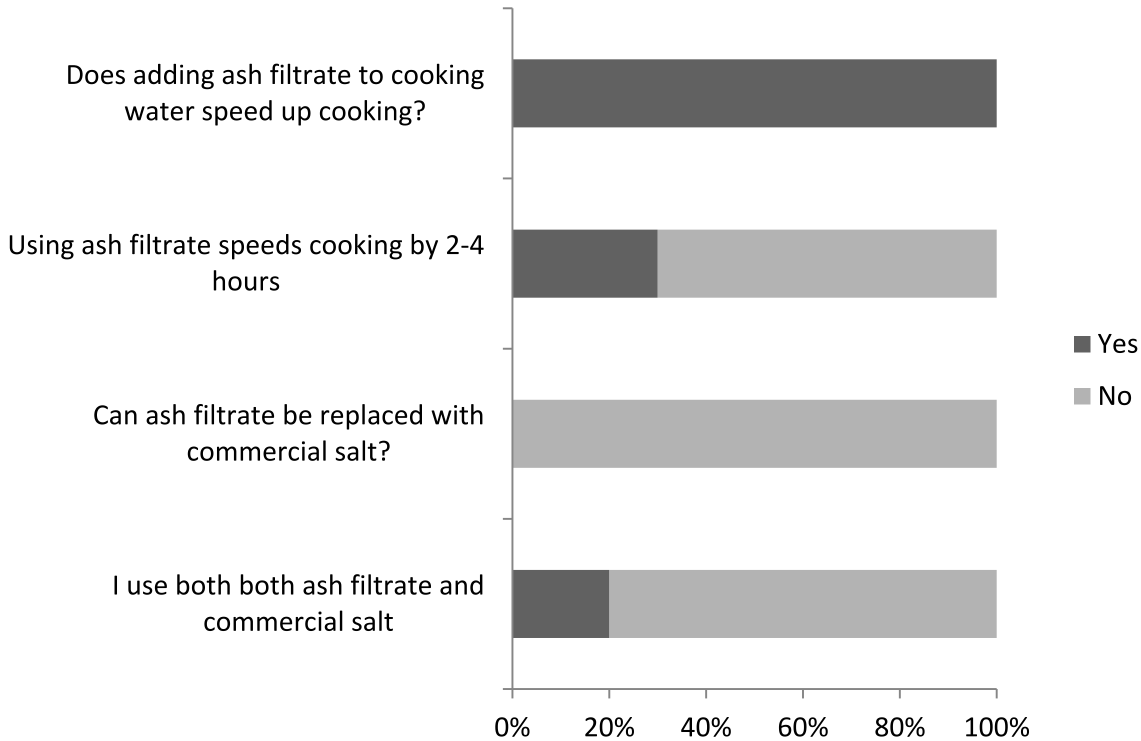

Figure 4. Percent response of cooking time related interview responses (n=20). Every bar totals 100%, with “Yes” and “No” responses viewed as proportions of the bar.

all women stated that ash filtrate decreased cooking time and that the difference could be 2-4 h faster depending on the amount being cooked and the size of the fire (Figure 4). Note that in Figure 4, every bar totals 100%, with “yes” and “no” responses viewed as proportions of the bar. Other responses about actual time savings were less definitive but still suggested considerable time savings; “There is a big difference between food cooked with *kado atwona* [ash filtrate]...it is much faster”. Several respondents did say that ground salt could be used instead of ash filtrate, both for decreasing cooking time and to make the taste culturally acceptable. All interviewees further specified that substituting table salt for the ash filtrate was not possible because it wouldn’t have the same effect on cooking time. However, several women said that they use both ash filtrate to speed cooking and table salt after cooking to improve flavour.

During the interviews, 85% of women stated that they preferred beans cooked with ash filtrate for improved taste, smell, or both, which did not correspond to the statistical findings of the blind taste tests. Two women answered that they did not prefer to use it but that it was necessary, “For me, it is the culture that makes me use it but I don't like it”. There was one nonresponse. Several respondents said that they add table salt and other ingredients (e.g., peanuts) to the beans after they are cooked with filtrate, to further improve flavour.

Ash filtrate decreased cooking time as compared to either the control or table salt treatments, validating the anecdotal belief. Additionally, ground salt was found to decrease cooking time even more than the ash filtrate. Based on this finding that both traditional treatments sped up the cooking process, it is probable that they share similar properties and/or mechanisms of pectin degradation, confirming previous findings (Mamiro et al., 2011). Indeed, both treatments were highly alkaline (pH 9.6 (ground salt) and 10.5 (ash filtrate)) compared to either the control or table salt treatments (pH 7.7-8.2, respectively), and both contained high levels of elemental concentration, particularly sodium (ground salt) and potassium (ash filtrate) (Bergeson, 2014). The slightly basic pH of the table salt treatment is likely due to additional impurities in the salt (Varriano-Marston and de Omana, 1979). High concentrations of sodium and potassium, and an alkaline pH have all been shown to be important in the reduction of cooking time of legumes (Varriano-Marston and de Omana, 1979).

As the temperature at boiling was not found to be significantly different among treatments in this study, it could not be the cause of differing cooking times. The addition of a solute (e.g., salt) to a pure solvent (e.g., water) is known to elevate boiling temperature due to vapor pressure differential between the pure solvent and the solution (Andrews, 1976). This colligative property depends on the number of particles present in the solution. The lack of observed difference in boiling temperature in this study is likely because a small amount of solute was added, which did not contribute sufficient particles to change the temperature at a scale observable with our thermometers.

Another interesting anomaly, with respect to many other studies, was that the table salt treatment did not decrease bean cooking time as compared to the control, and actually took longer than the control to become texturally acceptable (Table 2). The use of NaCl has consistently been shown to increase the rate of softening and therefore decrease cooking time for hard- to- cook beans (Silva et al., 1981; Van Buren, 1986; de León et al., 1992). de León et al. (1992) found continually significant decreases in cooking time obtained with increasing ratios of monovalent to divalent ion concentration (increased Na^+, predominantly). By the methodology explained in de León et al. (1992), the ratio of monovalent to divalent ions in the plain (control) oven-dried beans (80 g) in this study was 4.2; the sum of monovalent ions (K^+ and Na^+) was 964 mg (919 mg K^+ + 45 mg Na^+) and the sum of divalent ions (Ca^{2+} and Mg^{2+}) was 228 (104 mg Ca^{2+} + 124 mg Mg^{2+}). The ratio of 4.2 in this study (Bergeson, 2014) was lower than the 4.6 ratio of the dried beans used in de León et al. (1992). The addition of 2 g of table salt, 2 g of ground salt, and 15 ml of ash filtrate treatment additives to 1 L of water and 80 g of dried beans would alter the ratio to 7.4, 4.9, and 5.1, respectively (Bergeson, 2014). In contrast to previous findings, the addition of table salt and increased monovalent to divalent ratio in this study did not decrease cooking time compared to the control. This may be due to differences in chemical composition of the commercial salts used in each study as refining processes are likely to differ between companies and countries of origin. The commercial salt used in this study could contain amounts of additional divalent ions not present in the solutions employed by de León et al. (1992). The different outcome may also be due to differences in methodology. de León et al. (1992) reported soaking the dry beans prior to cooking, but in this study beans were cooked from the dried state.

A major benefit to the shortened cooking time is the lessened pressure on fuel wood supplies. Deforestation continues to be a problem in Uganda, where the vast majority of the rural population uses wood or wood products (e.g., charcoal) for all domestic energy needs. It has been estimated that the average rural western Ugandan family will use approximately 8.4 kg of fuel wood per day for cooking meals (Wallmo, 1996), translating into slightly more than 3000 kg per year. Given that beans and legumes are also the most commonly cooked foods at that study site as well (Wallmo, 1996) and that they typically require the longest cooking time on the fire, it is reasonable to assume similar fuel wood requirements in rural Northern Uganda.

Experience gained by the cooking of beans for the sensory study portion of this research and multiple observations of meal preparation provided basic data on the length of time needed to cook beans on both charcoal stoves and over a fire. When the ash filtrate was added, a medium-sized (approximately 1.5 L) pot of beans required about two and a half hours to cook on a charcoal stove in a sheltered environment. While charcoal is becoming somewhat more prevalent in certain areas due to its benefits (e.g., long lasting nature, steady heat provision, and decreased emissions when cooking inside a building), many families cannot afford it. Fuel wood remains the dominant resource for cooking and other domestic requirements (van Gemert et al., 2013). Through observation and discussion, the same-sized pot of beans cooked with ash filtrate would take approximately four hours on a fire stove in a sheltered area. By extrapolating the findings of the controlled time trials where ash filtrate resulted in an 18% time difference, we could hypothesize that using the filtrate is saving women approximately one hour (63.2 min) when cooking over a fire. This translates into a sizable difference in the amount of fuel wood necessary to cook beans either in plain water or with the ash filtrate.

The beneficial aspect of traditional additives in decreasing cooking time must be weighed against probable drawbacks. The high alkalinity of both treatments has been shown to negatively impact the bioavailability of some minerals (Mamiro et al., 2011), decrease fibre content (Wanjekeche et al., 2003), and have deleterious effects on various vitamins (Kaputo, 1996) and amino acids (Minka et al., 1999). In contrast, the high concentration of certain elements in the ground salt and ash filtrate may not only counteract the decreased bioavailability, but also be contributing levels of other elements that could be exceeding daily recommended intakes (Bergeson, 2014). Further, several interviewees stated that they also added table salt after cooking in addition to the use of ash filtrate in order to improve flavour. This introduces additional sodium to the consumed product. The amount will vary depending on preference, but based on observation it could range from one half (~3 g) to one (~6 g) teaspoon (730 mg to 1461 mg sodium, respectively, Bergeson, 2014) in a pot with 4-6 servings of 240 g cooked beans. A diet high in sodium (greater than 1600 mg/day for adults) is known to contribute to hypertension, which subsequently raises health concerns such as cardiovascular disease, stroke, and edema (SACN, 2003). Lastly, protein content and availability has been shown to react differently with various types of salt; ground salt may slightly increase protein content (Onwuka and Okala, 2003; Wanjekeche et al., 2003), while table salt has a negative effect on protein efficiency ratio and protein content (de León et al., 1992; Onwuka and Okala, 2003).

Sensory evaluation across study sites yielded surprising results given anecdotal beliefs and interview responses. Beans cooked in ash filtrate were not well scored and almost exclusively the second to last preferred of all treatments. The sole parameter which rated beans cooked with ash filtrate over that of the control was improved texture (Table 2), probably due to the effect of alkalinity on breakdown of legume cell properties (Ankrah and Dovlo, 1978; Varriano-Marston and de Omana, 1979; Uzogara et al., 1990; Onwuka and Okala, 2003). However, the high alkalinity of the ash filtrate treatment was likely the reason why beans cooked with the ash filtrate scored lowest for bitterness. Also unexpected was the preference for the ground salt treatment as prior research results indicated that it contributed to an unpleasant colour (Wanjekeche et al., 2003) and flavour (Onayemi et al., 1986; Onwuka and Okala, 2003). Addition of ground salt can cause beans to turn a darker, less appealing colour which has resulted in low acceptability (Onayemi et al., 1986; Wanjekeche et al., 2003). The same results were not found in this study, perhaps because black beans were used and the colour variability was less apparent than with the lighter coloured beans used previously. The flavour however, was clearly preferred in the ground salt treatment and the table salt treatment. Both of these treatments contain higher sodium content than the other treatments, suggesting that this is an important contributor to sensory acceptability.

In comparison of study sites, the ash filtrate treatment was not the most preferred treatment at three of the four sites, although rated equal to the ground and table salt treatments by respondents only at Tit village (Figure 3). All other sites rated beans cooked with ash filtrate very poorly, and only slightly better than those cooked in distilled water. Participants at the Dog Abam site preferred beans cooked in both salt treatments by a large margin over those cooked in the control and ash filtrate treatments, suggesting a greater affinity for sodium. Respondents from Telela showed a strong preference for beans cooked in table salt. This village is located closest to a large town (Lira) and it may be that availability of table salt is easier, thus developing a preference for its use, or that traditional customs are somewhat less relied upon, thus lessening the preference for ground salt and ash filtrate. In contrast, respondents from the Arok study site greatly disliked the table salt treatment compared to participants from all other sites (Figure 3). The reason for this was not apparent, other than local preferences, as this study site was located not far from Dog Abam and no observable differences in these study sites were identified during data collection. However, the difference may be due to factors not identified in this study. Participants from Tit showed preference for any cooking additive over the control, which may be a function of the villages' history. This village was the last of the four study sites to resettle after living at an Internally Displaced Persons (IDP) camp for many years. Scarcity of either table salt or traditional additives during those years may have subsequently made the availability of any additive welcome.

The results of statistical tests showed that both site and treatment were important in understanding differences in preferences, as was the interaction between them. It was anticipated that treatment would affect sensory evaluation, but it is interesting that site (location) also affected preference. This suggests important cultural connections within small populations, which makes sense as women within these communities often share cooking duties and materials, such as ash. These women and their families may develop similar preferences for food. An important lesson from this finding is that there are different and complex traditions (e.g., cooking methods and/or amount of ash filtrate added) to consider among even small communities, that influence individuals' preferential tastes for food. It would be inaccurate to treat these communities as homogenous by assuming similar taste preferences throughout.

None of the demographic factors were found to be of statistical significance in contributing to observed differences among treatments. However, when interpreting these findings in a real life context, it must be noted that gender is important, as women perform a vast majority of domestic duties and as such, are responsible for how meals are prepared (Madge, 1994). The perceived benefits of using ash filtrate include improved taste and smell of food, as well as decreased cooking time for hard-to-cook foods. The distinct flavour imparted by the filtrate has resulted in it being used ubiquitously by households, and subsequently becoming a culturally obligatory practice. The practical benefit of decreased cooking time reduces daily workload for women, by reducing the number of hours of meal preparation and the time spent on associated activities (e.g., collection of fuel wood). The results of the blind taste tests in this study may be used to identify preferences between study sites and form a basis from which to initiate an individualized conversation with women from each community.

Several factors which may have influenced the dislike for beans cooked with ash filtrate in this study need to be considered. While every attempt was made to replicate common cooking practices, women in this region are used to preparing their own food and so have personal preferences that cannot be duplicated in every case (e.g., such as amount of filtrate to add and how long to cook the beans). Those interviewed indicated that the over-addition of filtrate creates very bitter tasting beans, and as the filtrate treatment scored poorly for bitterness (Table 2) it may be that the amount used was not in accordance with all household preferences. However, low scores across most parameters for the beans cooked in ash filtrate treatment suggest a general dislike. Also, refrigeration is very rarely used in this area and while refrigerated samples were warmed to ambient temperature before testing, this may have impacted taste. Lastly, cooked beans are always served with a sauce made from the remains of cooking water and addition of peanuts, salt, and/or other additives. The retention of this sediment likely provides a large portion of the flavour and so the taste differences between drained bean samples would be very subtle. In a region with very limited exposure to novel foods or cooking practices, participants may have had difficulty in differentiating specific sensory parameters in an atypically cooked food such as plain dry beans.

Conclusion

To date, it does not appear that a study using traditional salt(s) as a comparable soaking medium has been conducted. Given the reduction of cooking times with traditional additives in this study, it may be that their use would reduce soaking time equally, if not faster, than table salt. Further investigation is needed. Adding table salt to the soaking water hastens the process even further, thus reducing the opportunity for bacterial growth.

Legumes cooked with ash filtrate, while identified as being culturally preferred, did not rank well with legumes cooked with ground salt and table salt in blind testing. Given the contradictory findings among study sites, as well as between this research and other studies, sensory evaluations pertaining to specific populations or areas should always be conducted to identify area-relevant preferences.

Conflict of interests

The authors have not declared any conflict of interest.

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REFERENCES

Andrews FC (1976). Colligative properties of simple solutions. Science 194:567-571.

Ankrah EK, Dovlo FE (1978). The properties of trona and its effect on the cooking time of cowpeas. J. Sci. Food Agric. 29:950-952.

Bergeson TL (2014). Use of filtrate from crop residue ash for cooking in rural households in Northern Uganda. Master's Thesis, University of Northern British Columbia.

Chambers R (1997). Whose reality counts? Putting the first last. Rugby: Intermediate Technology Publications.

de León LF, Elias LG, Bressani R (1992). Effect of salt solutions on the cooking time, nutritional and sensory characteristics of common beans (*Phaseolus vulgaris*). Food Res. Int. 25:131-136.

Van Gemert F, Chavannes N, Nabadda N, Luzige S, Kirenga B, Eggermont C, de Jong C, van der Molen T (2013). Impact of chronic respiratory symptoms in a rural area of sub-Saharan Africa: an in-depth qualitative study in the Masindi district of Uganda. Prim. Care Respir. J. 22:300-305.

Devereux S, Hoddinot J (1993). Fieldwork in developing countries. Boulder: Lynne Rienner Publications.

Gotelli NJ, Ellison AM (2004). A Primer of Ecological Statistics. Sinauer Associates, Inc.: Sunderland, MA.

Kaputo MT (1996). The role of ashes and sodium bicarbonate in a simulated meat product from chikanda tuber (*Satyria siva*). Food Chem. 55:115-119.

Le Roux B (1998). Community-owned development amongst marginalized San communities of the Kalahari, as adopted by a san community development organization. Working Paper in Early Childhood Development No. 22. The Hague: Bernard van Leer Foundation.

Madge C (1994). Collected food and domestic knowledge in The Gambia, West Africa. Geogr. J. 160:280-294.

Makanjuola AA, Beetlestone JG (1975). Some chemical and mineralogical notes on kaun (trona). Niger. J. Min. Geol. 10:31-41.

Mamiro P, Nyagaya M, Kimani P, Mamiro D, Jumbe T, Macha J, Chove B (2011). Similarities in functional attributes and nutritional effects of magadi soda and bean debris-ash used in cooking African traditional dishes. Afr. J. Biotechnol. 10:1181-1185.

Mikkelsen B (1995). Methods for development work and research. Thousand Oaks: Sage Publications.

Minka SR, Mbofung CMF, Gandon C, Bruneteau M (1999). The effect of cooking with *kanwa* alkaline salt on the chemical composition of black beans (*Phaseolus vulgaris*). Food Chem. 64:145-148.

Norman G (2010). Likert scales, levels of measurement and the "laws" of statistics. Adv. Health Sci. Educ. 15:625-632.

Onayemi O, Osibogun OA, Obembe O (1986). Effect of different storage and cooking methods on some biochemical, nutritional and sensory characteristics of Cowpea (*Vigna unguiculata* L. Walp*).* J. Food Sci. 51:153-160.

Onwuka UN, Okala O (2003). Effects of selected salts on the cooking time, protein content and sensory properties of African yam beans and cowpeas. Food Serv. Technol. 3:3-7.

Pratt B, Loizos P (1992). Choosing research methods: data collection for development workers. Oxford: Oxfam.

Reyes-Moreno C, Paredes-Lopez O (1993). Hard-to-cook phenomenon in common beans – a review. Crit. Rev. Food Sci. 33:227-286.

SACN (Scientific Advisory Committee on Nutrition) (2003). Salt and Health. The Stationary Office: London, England. Available at: http://www.sacn.gov.uk/pdfs/sacn_salt_final.pdf.

Sammy J, Opio C (2005). Problems and prospects for conservation and indigenous community development in rural Botswana. Dev. South. Afr. 22 (1):67-85.

Siegel A, Fawcett B (1976). Food Legume Processing and Utilization (with special emphasis on application in developing countries). International Development Research Center: Ottawa, Canada.

Silva CAB, Bates RP, Deng JC (1981). Influence of soaking and cooking upon the softening and eating quality of black beans (*Phaseolus vulgaris*). J. Food Sci. 46:1716-1720.

Stake ER (1995). The art of case study research. Thousnad Oaks: Sage Publications.

Uzogara SG, Morton ID, Daniel JW (1990). Influence of various salts in the cooking water on pectin losses and cooked texture of cowpeas (*Vigna unguiculata*). J. Food Biochem. 14:283-291.

Van Buren JP (1986). Snap bean texture softening and pectin solubilization caused by the presence of salt during cooking. J. Food Sci. 51:131-134.

Varriano-Marston E, de Omana E (1979). Effects of sodium salt solutions on the chemical composition and morphology of black beans (*Phaseolus vulgaris*). J. Food Sci. 44:531-536.

Wallmo K (1996). A comparison of traditional and improved cookstoves in western Uganda. M.Sc., Forestry, University of Florida, Gainesville, Florida.

Wanjekeche E, Wakasa V, Mureithi JG (2003). Effect of germination, alkaline and acid soaking and boiling on the nutritional value of mature and immature Mucuna (*Mucuna pruriens*) beans. Trop. Subtrop. Agroecosystems. 1:183-192.