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Full Length Research Paper

Similarities in functional attributes and nutritional effects of magadi soda and bean debris-ash used in cooking African traditional dishes

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***Magadi* soda and bean debris-ash have been used as condiments for a long time by various ethnic groups in East and Central Africa in cooking traditional dishes. The aim of the study was to investigate whether *magadi* soda and bean debris-ash had similar effects and functional attributes when added to traditional dishes during cooking. Reason for the addition of the two condiments has not been revealed by researchers. Mineral content, *in-vitro* bioavailability studies and pH of non-ashed and ashed *magadi* soda and bean debris were evaluated. The results indicated that high concentrations of sodium ions (30.2%) and potassium ions (64.2%) were observed in *magadi* soda and bean debris-ash, respectively. *In-vitro* iron and zinc bioavailability decreased significantly with the addition of *magadi* soda and bean debris-ash in maize, beans and sorghum.** Equally, the cooking time was significantly reduced. **The mean pH for both magadi soda (9.66) and bean debris-ash (9.75) were not significantly different indicating that both aqueous solutions had alkaline properties. The similarity in properties especially in mineral profile, alkalinity, decreased cooking time and lowered mineral uptake by *magadi* soda and bean debris-ash explain similar functionality in foods they are added to during cooking. Despite the similarities observed, communities should be informed of the negative nutritional effects of these condiments so as to diversify their meal patterns accordingly.**

Key words: *Magadi* soda, bean ash, traditional dishes, minerals, *in-vitro* bioavailability

INTRODUCTION

The Rift Valley of Kenya-Tanzania contains large number of alkaline lakes varying in salinity from almost fresh to salt saturated water. The most hypersaline waters are those of Lake *Magadi* in Kenya and Natron in Tanzania (Grant, 2006). *Magadi* soda, which is essentially the trona deposit harvested from Lake Natron and Lake *Magadi*, consists of a mixture of sodium sesquicarbonate, sodium chloride and other sodium salts (Muindi et al., 2006).

Both lakes, *Magadi* and Natron lie in the Africa's Great Rift Valley and are saline lake types. Temperatures range from 29 to 41°C giving a high evaporation rate of 3500 mm per year (Grant, 2006).

Magadi soda is often added to traditional foods such as dry cereals or grain legumes for the purpose of shortening the cooking times, improving taste and flavor. For many years, this has been the practice of many ethnic groups in East and Central African countries including Tanzania, Uganda, Rwanda, Kenya, Congo and Angola. Traditional dishes commonly cooked with *magadi* soda comprise a mixture of beans and green banana, known as *shiro* in Tanzania and *Katogo* in Uganda and mixture of whole

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maize and beans (*makande* in Tanzania and *githeri* in Kenya). As an alternative to *magadi* soda, some ethnic groups use bean debris-ash (*Phaseolus vulgaris* L.). Traditionally, bean pods are harvested, dried and stuffed into a jute/sisal bag or on a traditional woven mat and threshed using a small stick that breaks the pods and releases the grains. The grains are collected and bean pod debris burned to obtain bean debris-ash. The aim of this study was to investigate whether *magadi* soda and bean debris-ash had similar effects and functional attributes such as mineral content, pH and cooking time when added to hard to cook traditional dishes.

MATERIALS AND METHODS

Materials

Five random samples of *magadi* soda each weighing about ½ kg were purchased from 5 retailers at Himo open market in Moshi Rural district, Kilimanjaro, Tanzania. Bean debris was obtained from Morogoro at Sokoine University of Agriculture bean trial plots. Five random samples of dry mature beans, each lot weighing about 1½ kg were harvested and sun-dried for two days on a traditional woven mat. The beans were then threshed separating the bean grains from the debris. For each lot, about 100 g of bean debris was burned to ashes and stored for analysis. About 2½ kg each of the dry maize, beans and sorghum samples were purchased from Morogoro market, Tanzania.

Mineral analysis

One portion (5 g) of non ashed *magadi* soda was dissolved straight in 10 ml of concentrated HCl acid. The other portion was ashed in a muffle furnace maintained at 550°C for 2 h, cooled and dissolved in 10 ml of HCl acid (AOAC, 1995). Equally, 5 g of non ashed bean debris-ash was dissolved in 10 ml of HCL acid. The other 5 g was ashed in a muffle furnace maintained at 550°C for 2 h, cooled and dissolved in 10 ml of HCl acid (ashed bean debris) (AOAC, 1995). The ashing was performed in order to determine the actual inorganic constituents present in comparison to the non ashed samples. The portions were filtered in a Whatman Filter paper No.1 and mineral concentrations were read from Shimadzu Atomic Absorption Spectrophotometer (AAS) (UNICAM 919, England). In order to obtain the entire mineral profile, all the lamps available for various elements were employed on the AAS. These were for copper, iron, zinc, manganese, magnesium, calcium, potassium and sodium evaluation. Phosphorus was determined by a phosphorus analyzer machine (UNICAM, 5625, England).

In vitro bioavailability studies

Each of the dry cereal food samples, that is, maize, beans and sorghum were boiled in de-ionized water till cooked in five batches of about ½ kilogram each. The first batch was boiled in de-ionized water without *magadi* soda and bean debris-ash. The second and third batches were boiled in de-ionized water with about 20 g each of un-ashed and ashed *magadi* soda, respectively. The fourth and fifth batches were boiled in de-ionized water with about 20 g each of non-ashed and ashed bean debris, respectively. The 20 g is an average amount normally added when cooking the types of food in the households. Each batch was boiled for about 3 h. equally, for each batch the time taken till the food samples were cooked was noted. The cooking time was determined when a pin from a Matson cooker could penetrate about 20 to 25 bean grain without restraint. After boiling, about 10 g of each sample was dried in an oven at 105°C for 24 h.

After drying, *in vitro* bioavailability of iron and zinc by pepsin-pancreatin (P-P) method was carried out as described by Miller et al. (1981). 2 g of the dried food samples (maize, beans and sorghum) were weighed and 10 ml of Pepsin-HCl solution was added and incubated in a laboratory shaker maintained at 37°C for 2 h to simulate gastric conditions. At the end of 2 h, 15 ml of pancreatin-bile in tyrode buffer was added, pH was adjusted to 7.5 and incubation continued for 2 h. The digest was centrifuged at 10,000 g for 20 min and then filtered through Whatman filter paper No 41. Analysis of soluble iron and zinc was performed using the AAS (Shimadzu UNICAM 919, England).

pH determination

The pH of *magadi* soda and bean debris-ash was obtained by mixing 1 g each of non-ashed and ashed *magadi* soda and 1 g each of non ashed and ashed bean debris with 10 ml of de-ionized distilled water, respectively, to form aqueous solutions. The aqueous solutions obtained were filtered by Whatman filter paper No 40. Using a digital pH meter; the electrode was dipped into each solution and the pH read directly from the display.

Data analysis

Computation of the actual concentrations of minerals in the samples and descriptive analysis of the data was done using Microsoft excel software (Microsoft office, 2003). The SPSS software (SPSS version 12) was used to compute inferential statistics. Analysis of variance of the results was done at 95% confidence interval ($P \leq 0.05$) using Tukeys Honestly Significant Difference. Homogeneity test was performed to determine homogenous sets.

RESULTS

The profile of minerals in *magadi* soda and bean debris-ash on dry matter basis and the respective pH levels are presented in Table 1. Mineral content of ashed and non-ashed *magadi* soda samples for copper, calcium, zinc, manganese magnesium, potassium and phosphorus did not differ significantly ($P \leq 0.05$). However, there was a significant difference ($P \leq 0.05$) for iron and sodium in mineral content in ashed and non-ashed *magadi* soda samples. Sodium levels were significantly ($P \leq 0.05$) lower in ashed and non-ashed bean debris, while in ashed and non-ashed *magadi* soda samples, the mean sodium content was significantly higher ($P \leq 0.05$) with an average of about 31 and 29%, respectively. Comparatively, sodium concentrations were higher than all the other minerals in non-ashed and ashed *magadi* soda. Similarly, the levels of potassium, magnesium and calcium in that order, were comparatively high in bean debris-ash when compared to *magadi* soda. Potassium concentrations were much higher than all the other minerals in non-ashed (65%) and ashed (64%) bean debris samples. Analysis showed that, all the concentrations of identical minerals did not differ significantly ($P \leq 0.05$) in

Table 1. Mineral content and pH of *magadi* soda and bean debris samples.

Mineral	*Magadi* soda sample		Bean debris sample	
	Non-ashed	Ashed	Non-ashed	Ashed
Copper (ppm)	6.68 ± 0.13[a]	6.24 ± 0.11[a]	24.18 ± 1.13[b]	24.80 ± 0.73[b]
Iron (ppm)	6063.92 ± 2.91[c]	6059.46 ± 0.48[b]	1049.56 ± 0.51[a]	1048.80 ± 1.43[a]
Zinc (ppm)	9.94 ± 0.27[a]	9.40 ± 0.10[a]	40.38 ± 0.40[b]	40.04 ± 0.41[b]
Manganese (ppm)	86.72 ± 0.72[a]	81.66 ± 0.13[a]	664.46 ± 132.32[b]	723.28 ± 0.63[b]
Calcium (%)	0.86 ± 0.05[a]	0.88 ± 0.04[a]	3.44 ± 0.26[b]	4.08 ± 0.85[b]
Magnesium (%)	0.40 ± 0.10[a]	0.48 ± 0.04[a]	3.90 ± 0.69[b]	4.44 ± 0.13[b]
Potassium (%)	0.44 ± 0.09[a]	0.36 ± 0.05[a]	64.66 ± 8.35[b]	63.74 ± 0.26[b]
Sodium (%)	31.10 ± 0.19[c]	29.18 ± 0.19[b]	0.11 ± 0.01[a]	0.11 ± 0.01[a]
Phosphorus (%)	0.12 ± 0.01[a]	0.12 ± 0.01[a]	0.73 ± 0.12[b]	0.81 ± 0.81[b]
pH	9.65 ± 0.01[a]	9.66 ± 0.01[a]	9.74 ± 0.01[b]	9.75 ± 0.01[b]

Values of respective minerals along rows with the same superscripts for *magadi* and bean debris-ash samples are not significantly different at P ≤ 0.05.

Table 2. Percent of *in vitro* mineral bioavailability and cooking time after addition of *magadi* and bean debris-ash in some hard to cook foods.

Food type cooked	Mineral content	No addition of *magadi* or bean debris-ash	Addition of non-ashed *magadi*	Addition of ashed *magadi*	Addition of non-ashed bean debris	Addition of ashed bean debris
Percentage of bioavailable iron						
Maize	1.98 ppm Fe	4.1[b]	3.4[a]	3.3[a]	3.4[a]	3.2[a]
Beans	8.72 ppm Fe	5.2[b]	3.3[a]	3.3[a]	3.5[a]	3.4[a]
Sorghum	1.5 ppm Fe	3.8[d]	2.2[a]	3.4[c]	3.1[b]	3.2[b]
Percentage of bioavailable zinc						
Maize	0.52 ppm Zn	3.4[c]	3.0[b]	2.8[b]	2.2[a]	2.3[a]
Beans	3.32 ppm Zn	5.5[d]	4.2[c]	4.2[c]	3.9[b]	3.6[a]
Sorghum	0.4 ppm Zn	3.3[c]	2.9[b]	2.7[b]	2.0[a]	2.1[a]
Cooking time (min)						
Maize		345[a]	252[b]	250[b]	258[b]	255[b]
Beans		180[a]	125[b]	120[b]	133[b]	130[b]
Sorghum		240[a]	175[b]	170[b]	173[b]	171[b]

Percentages of respective mineral along rows with the same superscripts for *magadi* and bean debris-ash samples are not significantly different at P≤0.05.

the ashed and non-ashed bean debris samples.

The mean pH of aqueous solutions of *magadi* soda and bean debris-ash was higher than 9. The results showed that both aqueous solutions were alkaline although bean debris-ash was more alkaline (pH 9.75 ashed and 9.74 non-ashed) as compared to *magadi* soda (pH 9.65 for ashed and 9.64 for non-ashed).

The *in vitro* bioavailability studies as summarized in Table 2 showed that percent iron and zinc significantly (P≤0.05) decreased in the foods cooked with *magadi* soda and bean debris-ash when compared to the percentage in foods cooked without *magadi* soda and bean debris-ash. Bioavailable iron was significantly reduced by 37, 20 and 11% in beans, maize and sorghum, respectively when *magadi* soda was added and by 35, 22 and 16 % in beans, maize and sorghum, respectively, when bean debris-ash was added. In foods cooked with *magadi* soda, percent zinc were reduced by 34, 18 and 18%, while in foods cooked with bean debris-ash, zinc was reduced by 35, 32 and 37% in beans, maize and sorghum, respectively. In addition, cooking time was significantly reduced when *magadi* soda and bean debris-ash were added (Table 2). Cooking time decreased by 28% in beans, 33% in maize and 29% in sorghum when cooked with *magadi* soda. Bean debris-ash shortened cooking time by 26% in beans, 28% in maize and 29% in sorghum.

DISCUSSION

Mineral profile carried out showed that in *magadi* soda, the proportion of sodium ions was higher than the other minerals, while in bean debris-ash, potassium proportion was higher. Potassium and sodium belong to the same group in the periodic table and their ions form strong alkalis in aqueous solutions of potassium hydroxide and sodium hydroxide. Calcium hydroxide as well forms strong alkaline solution (Christensen et al., 1998). Therefore, the alkalinity might have been brought about by high concentration of potassium and calcium ions in bean debris-ash, while the high concentration of sodium ions might have been the cause of the alkalinity in *magadi* soda. The strong alkalinity was further confirmed by the pH of the aqueous solutions of *magadi* soda and bean debris-ash with 9.65 in *magadi* soda and more than 9.75 in bean debris-ash. The fact that these two condiments are used separately by various ethnic groups in similar foods proves analogous functionality of the condiments in the foods, which they are added to during cooking. According to Muindi et al. (2006) *magadi* soda, is added in these traditional foods basically for two reasons: First, due to its alkalinity properties; *Magadi* has the ability to soften the testa of cereal and legume grains such as sorghum, millet, maize and beans so that they can be cooked quickly and secondly, *magadi* imparts a peculiar flavour and smell to the food in question. Communities that use bean debris-ash to cook hard dry cereals like maize, sorghum and beans revealed that these foods cook faster using less fuel (J. Emmanuel, Tchenzema Village, Tanzania, Personal communication). Similar results were observed by Muindi et al. (2006) for the treatment of sorghum with magadi soda. This phenomenon was also confirmed by this study. The decrease in cooking time ranged from 26 to 33% saving about 50 to 95 min of cooking depending on the type of food.

Despite the rich mineral profile of *magadi* soda and bean debris-ash and the shortened cooking time, bioavailability of minerals in these foods may be compromised due to alkaline conditions. Experiments done on *in-vitro* mineral bioavailability showed that all foods cooked with *magadi* soda and bean debris-ash had significant ($P \leq 0.05$) reductions in bio-available minerals (iron and zinc). The low biovailability of minerals might result into specific mineral deficiencies leading to a number of related diseases, thus affecting individuals nutritionally. Similar trend was observed by Mtimuni et al. (2000) on animal hay when supplemented with *magadi* soda.

Various studies have documented the link between food consumption and its utilization in the body along the gastrointestinal tract. According to Anthony and Chandra (1998), HCl solubility of minerals and trace elements under simulated gastric conditions, is an indicator of bioavailability from foods. However, the digestion of minerals mainly occurs in the duodenum where some of the non-heme iron and other minerals are absorbed (Hallberg, 1981; Oski, 1993; Cook and Reddy, 2001). In the stomach, the pH is between 1 to 3 due to the presence of HCl in the gastric secretions, while in the duodenum, the pH is alkaline in the range of 7.5 to 8.0 (Rao and Prabhavathi, 1978; Miller et al., 1981). A pepsin-pancreatin digestion process simulating mineral digestion in the gastrointestinal tract is therefore a stronger indicator of the bioavailability of minerals from foods compared to HCl-pepsin digestion. This is important in the sense that minerals in the two-pH systems behave differently. In the acidic medium of the stomach, minerals are soluble since they combine with HCl to form chlorides (Hallberg, 1981; Miller et al., 1981; Mamiro et al., 2001). As the pH is raised further (from 1.2 to 7.5) to simulate duodenal conditions, solubility decreases due to formation of hydroxides, which precipitate out and are unavailable for absorption (Rao and Prabhavathi, 1978). Thus consuming foods that have been cooked using *magadi* soda/bean debris-ash might further lower the amount of mineral uptake in the body.

Conclusion

It can be concluded from this study that decrease in *in vitro* mineral bioavailability, alkaline conditions resulting from high concentration of alkaline elemental profile, similarity in pH ranges and improvement in flavour and smell suggest similar functions of *magadi* soda and bean debris-ash. Despite reduction in cooking time and flavour enhancement of hard to cook dishes, addition of *Magadi* soda or bean debris-ash lowers mineral bioavailability. It is imperative that communities be informed of the negative nutritional effects of these condiments so as to diversify their meals accordingly.

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