Bots. J. Agric. Appl. Sci (2013) 9 (Issue 2) 104-108

BOJAAS

SHORT COMMUNICATION

Effect of sorghum variety on chemical composition and in vitro digestibility of malted grains from Botswana

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ABSTRACT

This study investigated the effects of variety of sorghum on nutritional levels of malted grains. Unscreened grains of BSH1, Mahube, Phofu and Segaolane were malted and analysed for crude protein, minerals, fiber, organic matter and *in-vitro* digestibility. Malts from red coloured sorghum varieties (Mahube and BSH1) had significantly higher ($P<0.01$) crude protein, iron, copper and zinc. This could mean malting liberated more protein, iron, copper and zinc from protein-mineral phytates and oxalates in the red coloured sorghum grains than the white coloured grains. On average, malts from white grain sorghum varieties (Segaolane and Phofu) had higher neutral detergent fiber (52.0%) than those from red coloured varieties (42.3%). While malts from red coloured grains had higher percentage of acid detergent fiber (5.6 %) than those white grains (4.5 %), they (red coloured grains) were found to be more digestible than those from white coloured grains. It may be concluded that since red coloured sorghum grains are disliked by people for their bitter taste, they may be malted and be used for animal feed and spare the white coloured sorghum grains for human food. Using malted sorghum grains as a substitute to maize grains in animal feeds is likely to reduce the fast rising price of chicken and pig feeds.

Keywords Digestibility, malts, minerals, protein, sorghum grains

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Publisher: Botswana College of Agriculture

INTRODUCTION

Grain sorghum performs better than maize in Botswana climatic conditions (CSO, 2008), and this gives it a better advantage over maize in contributing towards reducing local food and livestock feeds shortage. However, it is maize grain that is mostly used in livestock feeds, and the competition for its use between man and livestock has made it expensive in developing countries (Adeniji and Ehiemere, 2003). The increasing human population and animal sector in Botswana requires various technologies to process locally produced grain sorghum into various products and hence reduce food and feed imports. If such processed sorghum grain is incorporated in livestock rations (Madibela and Lekgari, 2005), then it could replace a substantial amounts of maize grains in most livestock rations. Nutritive values of sorghum and maize are comparable (Macala *et al*., 1995; Subramanian and Metta., 2000). However, sorghum grain contains anti-nutritional factors that make it less digestible than maize (Chen *et al*., 1994; Etuk *et al*., 2012) and thus lowering its feeding value. These anti-nutritional factors include tannins and phytic acid (Chibber *et al*., 1980; Mohammed *et al*., 2011), and lowers palatability and protein utilization in non-ruminants (Gualtieri and Rapaccini, 1990). The starch-protein matrix found in sorghum grain is more resistant to moisture and enzyme penetration than it is the case in other cereal grains (Rooney and Pflugfelder, 1986), and this makes sorghum grain less digestible to animals. Despite the anti-nutritional constrains that may come with feeding sorghum grains, there are various processing methods that can improve nutritive value of sorghum grain. Malting sorghum grains reduced the amount of its oxalate by 34.13 %, tannin by 8.45 %, trypsin inhibitor activity by 36.5 % and phytate by 66 % (Ogbonna *et al*., 2012). In addition, Abubakar *et al* (2006) stated that malting and chemical treatments can improve protein digestibility and palatability of sorghum grain. Malting process involves steeping/soaking, germination and drying and this process liberates phyto-enzymes that effectively digest corneous protein matrix of the grain endosperm (Makokha *et al*, 2002), and thus making the grain more digestible. Since malting reduces the content of anti-nutritional factors and increases protein content of sorghum grain (Etuk *et al*., 2012), it could be effectively utilized in livestock and poultry feeds. Oduguwa *et al* (2006) found increased intake of nitrogen and weight gain amongst sheep supplemented with malted sorghum sprout. The Department of Agricultural Research in the Ministry of Agriculture has developed several sorghum varieties for both food and beer making in Botswana. There are opportunities to utilise surplus sorghum grain in livestock diets if sorghum production could be increase (Madibela and Lekgari 2005). However, there is no information on the processing and technology to enhance the quality of sorghum for livestock feeding. Therefore, the aim of this study was to determine the nutritional attributes of malted grains from locally developed sorghum with the view of using it in livestock diets.

MATERIALS AND METHODS

Preparation of Samples

Unscreened sorghum grains of BSH1, Mahube, Phofu and Segaolane varieties were sourced from Department of Agricultural Research (DAR) Seed Multiplication Unit in Sebele Research Station, Gaborone. The grains were soaked in a plastic container covered with a jute bag for 48 hours at room temperature, and then spread on hessian bag and allowed to germinate for 5 days under dark conditions. After germination, the malted grains were sun dried. No effort was made to separate the germinated from the un-germinated grains. Grains were placed in paper bags and dried in a forced air oven (Ecotherm – Labotec) at 60^{o}C for 48 hrs. After drying the malted grains were ground with hammer mill to pass through a 2mm sieve.

Chemical Analysis

Duplicate samples were taken from each of the four (4) ground sorghum varieties for chemical analysis and *in-vitro* dry matter digestibility. The ground samples were analysed for ash, neutral detergent fibre (NDF), acid detergent fibre (ADF), nitrogen (Kjeldahl method) and minerals (wet digestion for macro- and dry digestion for micro-minerals), following the methods of (AOAC 1996). Calcium, copper (Cu), manganese (Mn), and zinc (Zn) were determined with an atomic absorption spectrophotometer and phosphorous with a ultra-violet spectrophotometer. *In-vitro* dry matter digestibility was estimated according to Tilley and Terry (1963) methods by incubating the samples in a thermostatically controlled circulating water bath. Rumen liquor was taken from a Tswana steer fed a mixture of *Cenchrus ciliaris* and *Lablab purpureus* (ratio of 1:1 DM basis at a rate of 8kg/day. The diet contained (g/kg DM) 76.8 crude protein, 7.8 calcium, 1.2 phosphorous, 776 NDF, 547 ADF and 904 organic matter.

Statistical Analysis

The General Linear Model (GLM) procedure (SAS 1990) was used to test the effects of sorghum variety on chemical composition and *in-vitro* dry matter digestibility. Differences between varieties were tested for significance using least significance difference (LSD). Means are reported as least square means where minimum significance was set at $P < 0.05$.

RESULTS

The crude protein (CP) levels of malted sorghum grains from the four tested sorghum varieties (Table 1) were statistically different ($P<0.001$). Malted grains of Mahube variety had the highest CP level (13.8 %) followed by those of BSH1 variety while Phofu variety produced malted grains that had the lowest crude protein level (10.1%). Statistically similar levels of calcium and phosphorus were observed in all tested sorghum grains. Amounts of manganese were high in Segaolane variety (15.3 mg/kg) and low in BSH1 (9.7 mg/kg). However, these manganese values were observed to be statistically similar.
The levels of iron ($P < 0.05$), copper ($P < 0.01$) and zinc ($P < 0.05$) in malted sorghum grains were significantly different amongst the varieties. The malted grains of BSH1 variety had the highest amounts of copper and zinc while those of Phofu variety had lowest amounts of these minerals. High values of iron ($P < 0.05$) were observed in malted grains of Mahube (36.7 %) and BSH1 (36.0 %) while lowest iron content was noted in malts of Phofu variety. Statistically similar ($P > 0.05$) contents of NDF, ADF and DMD were found amongst all tested grains malts. However, BSH1 malts tended ($P = 0.099$) to have the high OMD (84.2 %).

DISCUSSION

The crude protein concentration of malted grains of Mahube (13.8 %) and Segaolane (12.3 %) varieties in this study is higher than crude protein content of about 11 % of unmalted grains of both varieties in Makokha *et al* (2002) and Macala *et al* (1995) studies. Badubi (2012) recently documented crude protein of 11.5 % and 11.9 % for unmalted Phofu and Segaolane grains. The average crude protein (12.4%) of all malted sorghum grains was similar to (12.3 % CP) but higher than 11.62 % CP found in malted sorghum grains by Obizoba (1988) and Abubakar *et al* (1995) respectively in Nigeria. However, the average crude protein in this study was lower than 13.1 % found in malted sorghum grains by Beta *et al* (1995), and this slight crude protein difference could be attributed to difference in sorghum varieties and the effect of sodium hypochlorite treatment used on grains in Beta *et al* (1995) work before grains were germinated. Malts from red coloured sorghum varieties had high average CP (13.6 %) compared to 11.2 % CP of white coloured sorghum varieties, and this trend was also noted by Streeter *et al* (1993) and Etuk *et al* (2012).

Table 1. Chemical composition and in vitro dry matter digestibility (%) of four varieties of malted sorghum

Parameters	Varieties					Effects	
	BSH1	Mahube	Phofu	Segaolane	SEM	Variety	Replication
Crude Protein	13.5[a]	13.8[a]	10.1[c]	12.3[b]	0.22	***	*
Phosphorus	0.26	0.26	0.27	0.26	0.020	NS	NS
Calcium	0.13	0.03	0.04	0.04	0.049	NS	NS
Iron (mg/kg)	36.0[a]	36.7[a]	23.7[c]	26.7[b]	2.11	*	0.052
Copper(mg/kg)	8.0[a]	6.0[b]	5.7[b]	6.0[b]	0.29	**	NS
Manganese(mg/kg)	9.7	12.3	13.0	15.3	1.15	0.067	NS
Zinc (mg/kg)	38.3[a]	23.6[b]	20.0[c]	23.0[b]	1.82	*	0.088
NDF[1]	36.5	48.8	51.7	52.3	6.72	NS	NS
ADF	6.0	5.2	4.7	4.3	0.53	NS	NS
OMD	84.2	75.8	57.0	59.2	7.21	0.099	NS
DMD	83.3	74.1	57.3	59.6	7.41	NS	NS

*[1]NDF = neutral detergent fibre; ADF = acid detergent fibre; OMD = organic matter digestibility; DMD = in vitro dry matter digestibility; NS = P>0.05; * = P<0.05; ** = P<0.01; *** = P<0.001*

However, the red grain sorghum types are reported to contain high amount of tannins (Myer *et al*., 1983) and this may result in low protein digestibility (Etuk *et al*., 2012) when fed to animals. While red sorghums represented here by BSH1 and Mahube may have high tannin levels, Table 1 shows that malts from these varieties were more digestible than those from Phofu and Segaolane. This could mean that grains from BSH1 and Mahube varieties had absorbed more moisture leading to higher hydrolysis activity than those from Phofu and Segaolane varieties. This is because soaking and fermentation processes of sorghum grain reduced its tannins levels (Kumar *et al*., 2005; Etuk *et al*. 2012). Tannins reduction also increases as soaking time of sorghum increases (Ochanda *et al* 2010). For instance Ogbonna *et al* (2012) found that malting white sorghum grains reduce its tannin and trypsin inhibitor by 8.45 % and 36.5 % respectively. Even though sorghum grain has high levels of indigestible kaffrin protein (Makokha *et al*., 2002), animals with saliva that contains high proline protein like browsers are reported to utilize sorghum grains efficiently (Hagerman, 1989; Streeter *et al*., 1993). This could mean that feeding unmalted sorghum to those animals with low proline saliva like sheep and cattle may result in poor performance due to low availability of grain protein. On efficiency of sorghum utilization by non-ruminants, Abubakar *et al* (2006) found that rabbits fed malted sorghum grain had significantly higher weight gain than those fed unmalted sorghum. The difference could be due to reduced available protein and minerals held in protein-mineral-phytate complexes in unmalted sorghum grains. Various authors had reported improved protein digestibility in malted grains (Singh *et al*., 1999; Odugwa *et al*., 2006; Akinola *et al*., 2012).

Iron is of paramount importance in the nutrition of pigs (Rincker *et al*., 2004). The average iron level found in this study was 30.8 mg, and is less than iron content (40 mg) found in raw sorghum grains used by Elkhier *et al* (2008). This difference in iron values could be attributed to the malting processes or difference in varieties of sorghum use. Malted grains of Segaolane and Phofu varieties had even low values (25.2 mg) of iron content. Sorghum grains that had been malted usually have low iron content compared to unmalted ones since the process of malting had liberated iron ions from phytate complex (Elkhier *et al*., 2008) and the iron used during germination. This is because iron content could be reduced by 38.4 – 39.2% during germination (Afify *et al* 2011). Phytate complex does not only limit available iron, it also reduces the bioavailability of multivalent minerals like calcium, manganese, cobalt, zinc and copper (Sandstrom and Sandberg, 1992; Williams *et al*., 2005; Afify *et al*., 2011). In the present study zinc was increased in BSH1 while manganese was increased in Segaolane. Calcium as well as phosphorus concentrations were similar between sorghum varieties. The higher minerals in some varieties than other may imply liberalisation from the phytates and oxalates in the sorghum grains (Makokha *et al*., 2002; Ogbonna *et al*., 2012).

The phosphorus levels of malted grains in this study were not different between the sorghum varieties. This could be due to similar phytate content found in Red sorghum and White sorghum grains (Ochanda *et al*., 2010). Phosphorus is commonly bound to phytate while calcium is usually held by oxalate in grains (Afify *et al*., 2011; Ogbonna *et al*., 2012). Therefore, it is very important to release these minerals from anti-nutritional factors to improve nutritional value of sorghum grains. Ogbonna *et al* (2012) found that malting reduced phytic acid and oxalate by 66 % and 34.13 % respectively, and this could mean that feeding animals with malted sorghum during drought seasons in Botswana may reduce cases of aphosphorosis and other nutritional diseases. In addition, animals that rely much on true stomach for digestion like poultry, pigs and carnivores are also likely to be deficient in most minerals if fed unprocessed cereal grains. Malted grains of BSH1 and Mahube sorghum varieties had high values of *in vitro* digestibility (dry matter and organic matter) compared to those from Segaolane and Phofu. Both organic matter and *in-vitro* dry matter digestibility of malted grains of BSH1 and Mahube were found within a range of 74.1 % to 84.2 %, while those of Segaolane and Phofu had 57.0 – 59.6 % range. This high range of digestibility could be attributed to low level (36.5 % to 48.8 %) of neutral detergent fiber found in malted BSH1 and Mahube grains.

CONCLUSION

The process of malting improved the crude protein content and digestibility of sorghum grains. This improved nutritive value of sorghum grains shows that malted sorghum grains could be an alternative to maize grains in production of livestock feeds. Utilization of sorghum grains in livestock feeds is likely to improve livestock production in most farms since sorghum is widely grown in Botswana.

Conflict of interest ORM is the Chief Editor of BOJAAS

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