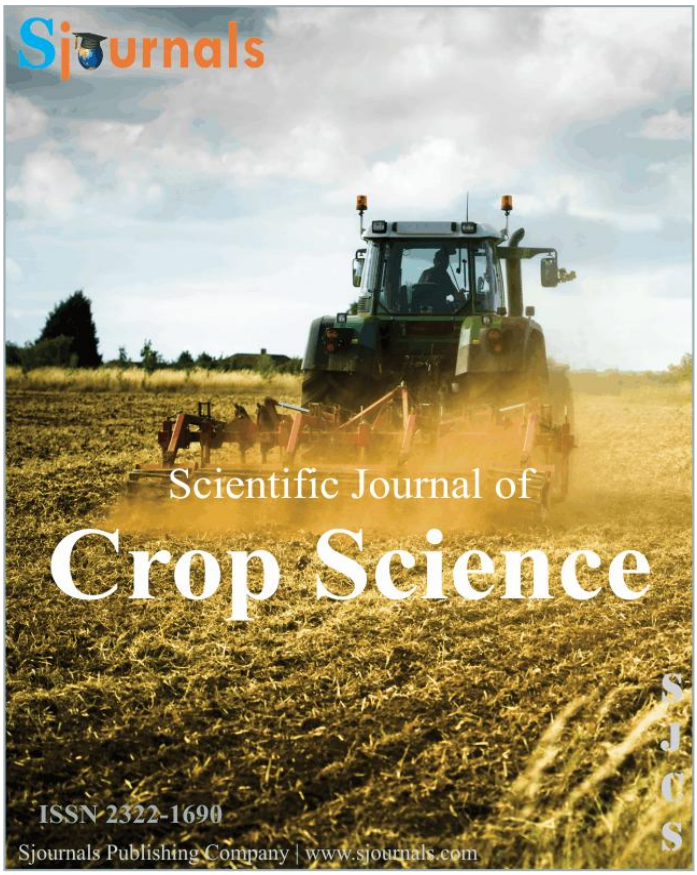

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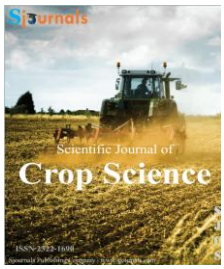

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Original article

Evaluation of the nutritional potential of safflower meal, after oil extraction, to be used as livestock feed

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ABSTRACT

A field experiment was carried out at Botswana University of Agriculture and Natural Resources, Notwane Farm to evaluate the nutritional potential of Safflower meal, after oil extraction to be used as potential livestock feed. The treatments were nine safflower genotypes (Kiama Composite (control), PI 537632-1038-USA, PI 30441-BJ-2621-Iran, PI 537598-Sina-USA, PI 407616-BJ-2131-Turkey, PI 537634-1040-USA, PI 537668-BJ-1085-USA, PI 314650-Milutin-114-Kazakistan and PI 306830-BJ-1632-India, laid in randomized complete block design. Safflower genotypes significantly ($P<0.05$) influenced the nutritional composition of safflower seed meal. The seed meal CP, NDF, ADF, ADL and ash contents significantly ($P<0.05$) varied between 19.3-22.5, 54.6-61.2, 45.0-50.7, 18.0-20.8, 1.10-1.60%, respectively. The seed meal mineral contents ranged from 6.98-7.90 mg/g P, 10.68-12.91 mg/g K, 8.78-10.61 mg/g Ca, 4.45-4.99 mg/g Mg, 90-120 µg/g Zn, 70-90 µg/g Fe, 40-50 µg/g Mn and 90-130 µg/g Cu. It was concluded that safflower genotype greatly influences nutritional value of seed meal after oil extraction and the meal can be used livestock feed.

1. Introduction

Safflower is a multipurpose oilseed crop grown mainly for its seed, which is used as edible oil (high quality), birdseed, livestock feed and industrial oil (Weiss, 2000; Dordas and Sioulas, 2008; Dordas and Sioulas, 2009; Istanbulluoglu, 2009; Emongor, 2010; Khalili et al., 2012). It is also used as cut flowers, vegetables, spice, for colouring, flavouring foods and making margarine, as medicines, for making red and yellow dyes for the textile industry, cosmetics (shampoos, hair and face cream, body lotion and perfumes), herbal teas and high quality paint (Shouchun et al., 1993; Bergland et al., 2007; Emongor, 2010). The uses of safflower have been recorded in China approximately 2,200 years ago (Dajue and Mündel, 1996). Traditionally, safflower was grown for its seeds, for colouring and flavouring foods, as medicines and for making red and yellow dyes, especially before cheaper aniline dyes became available (Weiss, 1971). In Egypt, dye from safflower was used to colour cotton and silk as well as ceremonial ointment used in religious ceremonies and to anoint mummies prior to binding. Safflower seeds and packets and garlands of florets have been found with 4000-year-old mummies (Weiss, 1971).

Safflower meal is the residue that remains after oil extraction (Jacob, 2015). The quality of the safflower meal is variable and depends on the amount of hulls and the extent of the oil extraction (Jacob, 2015). Safflower meal is slightly palatable as compared to other feed ingredients. However, its palatability can be improved by feeding it in mixed ration concentrates (Smith, 1996). For poultry and pig's diet, the use of decorticated safflower meal is possible if energy level is adjusted, by supplementation with lysine and methionine (Kohler et al., 1966; Darroch, 1990). In goats and sheep, safflower meal (20%) diet resulted in a better feed conversion ratio, decreased level of saturated fatty acids and increased the level of monounsaturated fatty acid in the kid and lamb meat (Pinto et al., 2011; Tufarelli et al., 2013). The use of safflower meal in total mixed ration (TMR) has also been reported to improve the atherogenic and thrombogenic indexes of the *Longis-simus dorsi* muscle of lambs/kids, which is functional product recommended in healthy balanced dietary to limit human cardiovascular diseases, as also reported in meat of rabbits, bulls and poultry (Peiretti and Meineri, 2008; Vicenti et al., 2009; Laudadio and Tufarelli, 2010).

Safflower meal is also a valuable ingredient for dairy cows, with no noticeable effect on flavour or odour of milk produced (Smith, 1996). Safflower meal can be a good substitute to linseed meal for dairy cattle (Smith, 1996). Adding 1 kg of safflower meal in the rations of Lithuanian dairy cows increased milk yield and milk fat by 1.4% and 0.37%, respectively. The substitution of 1 kg of concentrate by similar amount of safflower meal gave similar results (Juknevicius et al., 2005). Voicu et al. (2009) reported that inclusion of safflower meal in wheat silage had no adverse effect on feed intake and feed palatability, and resulted in an average daily gain higher than 1.4 kg/d in steers. Undecorticated safflower meal is considered to be high in protein (20-25%) with 30-40% fiber content (Gohl, 1982; Dajue and Mündel, 1996).

Botswana's location in the sub-tropical high pressure belt of southern hemisphere, in the interior of southern Africa and away from oceanic influence makes it experience low rainfall and high temperatures in summer. There is high inter-annual variability of rainfall and drought is a recurring element of Botswana's climate (Emongor, 2009). Drought adversely affects the already fragile food and agricultural situation in the country and seriously impairs the rural economy and socio-cultural structures. Due to the erratic, unreliable and poorly distributed rainfall accompanied by high temperatures, water becomes the most limiting factor to agricultural production in Botswana (Emongor, 2009). In Botswana, the annual precipitation and evapotranspiration ranges between 200-650 mm and 1800-3000 mm, respectively, depending on season (Emongor, 2009). Therefore, growing a drought and winter tolerant crop such as safflower will improve food security, reduce reliance on feed imports and improve income levels of farmers in Botswana. Therefore, the objective of this study was to evaluate the nutritional potential of safflower meal, after oil extraction, to be used as livestock feed.

2. Materials and methods

2.1. Study site

The experiment was carried out in Botswana University of Agriculture and Natural Resources (BUAN), Notwane Farm, which is located at 24°35'S and 25°58'E: 998 m above the sea level. The climate is semi-arid with average annual rainfall of 538 mm. Most rains falls in summer, which generally starts in the late October and continues to March or April. The soils are deficient in phosphorus, have low levels of nitrogen and organic matter

(Emongor et al., 2004; Emongor et al., 2012). The soils are shallow, ferruginous tropical soils, mainly consisting of medium to coarse grains and sandy loams with low water holding capacity and subject to crusting after heavy rains (De Wilt and Nachtengale, 1996). The experimental site has an average maximum and minimum temperature varying between 33.1-34.7 °C and 19.2-19.5 °C, respectively (Ramolemana, 1999).

2.2. Experimental design

The experimental design was a randomized complete block design with nine treatments replicated three times. The experiment was blocked because of the 1% slope in the experimental site. The treatments were nine genotypes of safflower (Kiama Composite, PI 537632-1038-USA, PI 3044-BJ-2621-Iran, PI 537598-Sina-USA, PI 407616-BJ-2131-Turkey, PI 537634-1040-USA, PI 537668-BJ-1085-USA, PI 314650-Milutin-114-Kazakhistan and PI 306830-BJ-1632-India).

2.3. Safflower meal processing and oil extraction

After safflower plants reached maturity, seeds were harvested and sun dried. The safflower seeds were then pressed using an electric oil expeller (Oil Love Natitimal Engineering Company, LTD, Korea). The oil expeller was pre-heated to a temperature of 180 °C for nutritional analysis. As oil was ejected from the machine, seed meal was also expelled from the other outlet.

2.4. Nutrient analyses

Safflower meal samples were dried at 66 °C for 72 hours in an oven for determination of dry matter content (AOAC, 2000). The dried samples were ground in a mill to pass a 1mm sieve screen for further analyses. Assays for NDF and ADF were done according to AOAC (2000), while ADL was performed using the adaptation of Van Soest detergent Scheme (ANKOM Daisy II Incubator) which uses the ADF method (Goering and Van-Soest, 1991). The amount of ash in the samples were ascertained by completely burning to ash sampled previously used in ADL procedure (ANKOM method) in a muffle furnace of 550-600 °C for 2 hours (AOAC, 2000). For crude protein and mineral analysis, 0.5 g of seed meal samples were first digested in 10 ml of concentrated sulphuric acid (98%) and 2 ml of 15-45% hydrogen peroxide in a digestion block heater for 8 hours, kept at 420 °C. After digestion, the samples were allowed to cool for 2 hours and transferred into 200 ml volumetric flasks and filled with distilled water to the mark. The samples were then to be used for the different analysis of minerals. Mineral analysis (P, K, Ca, Mg, Na, Fe, Zn, Mn and Cu) were determined using Inductively Coupled Plasma mass spectrometry (ICP-MS) machine (AOAC, 2000). Nitrogen (N) was determined by microkjedal method and CP estimated by multiplying the nitrogen (N) content by 6.25 (AOAC, 2000).

2.5. Statistical analysis

Data collected was subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS, 2011). The treatment means was separated using the Least Significant Difference (LSD) at P=0.05.

3. Results and discussion

3.1. Safflower seed meal composition after oil extraction

There were significant (P<0.05) differences in seed meal dry matter (DM) depending on the safflower genotype (Fig. 1). The variation in safflower meal dry matter ranged between 94.7-96.1% (Fig. 1).

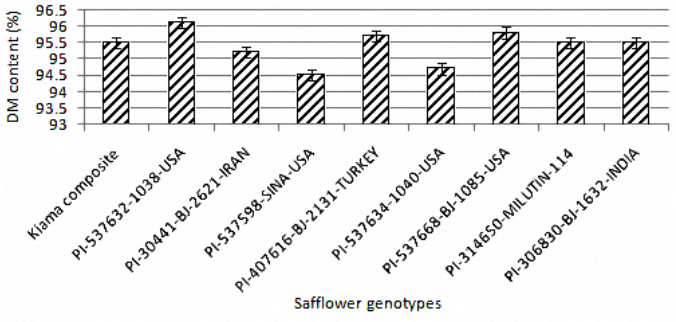

Fig. 1. Effect genotype on safflower seed meal dry matter.

The genotype PI 537632-1038-USA had a seed meal DM of 96.1%, which was significantly (P<0.05) higher than the meal DM of the genotype PI 537598-Sina-USA (94.5%), but there were no significant (P>0.05) differences in seed DM within other genotypes (Fig. 1). There was also a significant (P<0.05) effect of genotype on crude protein (CP) of safflower seed meal after oil extraction (Fig. 2). The crude protein (CP) content in the seed meal ranged between 19.3-22.5% depending on genotype (Fig. 2). The genotype PI 537598-Sina-USA (22.5%) had significantly (P<0.05) higher seed meal CP than all the other genotypes under study (Fig. 2). While the genotype PI 306830-BJ-1632-India had significantly (P<0.05) lower seed meal CP than all other genotypes under study (Fig. 2). The other genotypes did not differ significantly (P>0.05) on their meal CP contents, with exception of the genotypes PI 537598-Sina-USA and PI 306830-BJ-1632-India as described above (Fig. 2).

The seed meal NDF content did not significantly (P>0.05) differ among safflower genotypes (Fig. 2). However, the cake NDF among genotypes under study ranged between 54.6-61.2% [LSD=7.15%, P=0.05] (Fig. 2). Furthermore, the results of the study showed that acid detergent fiber (ADF) of safflower meal significantly (P<0.05) varied among genotypes (Fig. 2). The seed meal ADF varied between 45.0-50.7% depending on the genotype (Fig. 2). The genotypes PI 30441-BJ-2621-Iran and PI 537632-1038-USA had significantly (P<0.05) higher seed meal ADF than the genotypes PI 537634-1040-USA (Fig. 2). The seed meal ADF of the genotypes PI 30441-BJ-2621-Iran and PI 537632-1038-USA did not significantly (P>0.05) differ from that of the genotypes PI 306830-BJ-1632-India, Kiama composite, PI 407616-BJ-2131-Turkey, PI 314650-Milutin-114-Kazakistan and PI 537598-Sina-USA (Fig. 2).

No significant (P>0.05) difference was observed in the seed meal ADL content on the safflower genotypes under study (Fig. 2). The ADL content ranged from 18.0-20.8% (Fig. 2). However, Kiama composite had the highest seed meal ADL of 20.8%, while the genotype PI 306830-BJ-1632-India had the lowest seed meal ADL of 18.0% (Fig. 2). The seed meal ash content of the different safflower genotypes did not significantly (P>0.05) differ (Fig. 2). However, the seed meal ash content of the genotypes varied between 1.10-1.60% in safflower meals (Fig. 2).

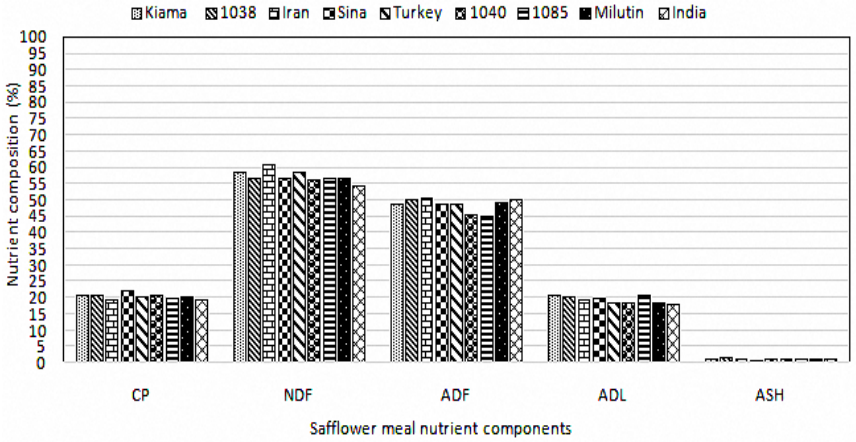

Fig. 2. Nutritional composition of safflower meal and genotype effect on meal CP, NDF, ADF, ADL and ASH.

3.2. Mineral composition of safflower meal

The P seed meal content of safflower genotypes significantly (P<0.01) differed (Table 1). The P content of the different safflower genotypes seed meal ranged between 6.98-7.90 mg/g (Table 1). The genotype PI 537668-BJ-1085-USA had significantly (P<0.01) higher seed meal P content (7.90 mg/g) than PI 407616-BJ-2131-Turkey, PI 314650-Milutin-114-Kazakistan, PI 537632-1038-USA and PI-306830-BJ-1632-India (Table 1). Also the P seed meal contents of the genotypes PI 537668-BJ-1085-USA, Kiama composite, PI 537598-Sina-USA, PI 537634-1040-USA and PI 30441-BJ-2621-Iran did not significantly (P>0.05) differ (Table 1). The safflower genotype PI 537632-1038-USA had the lowest seed meal P content (6.98 mg/g), but was not significantly (P>0.05) different that of the genotypes Kiama composite, PI 407616-BJ-2131-Turkey, PI 314650-Milutin-114-Kazakistan and PI-306830-BJ-1632-India (Table 1).

On the other hand, safflower genotypes did not significantly (P>0.05) influence the K, Ca and Mg contents of the seed meal after oil extraction (Table 1). The seed meal K, Ca and Mg contents ranged between 10.68-12.91 mg/g, 8.78-10.61 mg/g and 4.45-4.99 mg/g, respectively (Table 1). The seed meal Na content of safflower

genotypes significantly (P<0.05) differed (Table 1). The seed meal Na content of safflower genotypes ranged between 3.24-3.70 mg/g (Table 1). The genotype PI 407616-BJ-2131-Turkey had a seed meal Na content of 3.70 mg/g which was significantly (P<0.05) higher than that of all the other genotypes (Table 1). With exception of the seed meal Na content of the genotype PI 407616-BJ-2131-Turkey, the seed meal content of the other genotypes did not significantly (P>0.05) differ from each other (Table 1).

Furthermore, the seed meal micro elements of safflower genotypes under study did not significantly (P>0.05) differ (Table 1). The Zn, Fe, Mn and Cu contents ranged between 90-120, 70-90,40-50 and 100-130 (µg/g), respectively, depending on the genotype (Table 1). But as for Cu content, the genotype PI-314650-Milutin-114-Kazakistan with 130 µg/g was statistically (P<0.05) higher Kiama composite (Table 1).

Table 1
Mineral composition of safflower seed meal.

Genotypes	P (mg/g)	K (mg/g)	Ca (mg/g)	Mg (mg/g)	Na (mg/g)	Zn (µg/g)	Fe (µg/g)	Mn (µg/g)	Cu (µg/g)
Kiama composite	7.46^{abc}	11.49^{ab}	8.78^{a}	4.51^{a}	3.30^{b}	100^{a}	70^{a}	40^{a}	90^{b}
PI-537632-1038-USA	6.98^{c}	12.13^{ab}	9.50^{a}	4.45^{a}	3.24^{b}	100^{a}	90^{a}	50^{a}	110^{ab}
PI-30441-BJ-2621-Iran	7.68^{ab}	11.89^{ab}	10.05^{a}	4.49^{a}	3.29^{b}	90^{a}	80^{a}	40^{a}	120^{ab}
PI-537598-Sina-USA	7.85^{a}	12.91^{a}	9.53^{a}	4.56^{a}	3.26^{b}	100^{a}	90^{a}	40^{a}	120^{ab}
PI-407616-BJ-2131-Turkey	7.17^{c}	10.69^{b}	9.74^{a}	4.74^{a}	3.70^{a}	120^{a}	80^{a}	50^{a}	110^{ab}
PI-537634-1040-USA	7.75^{a}	12.12^{ab}	10.61^{a}	4.74^{a}	3.29^{b}	120^{a}	80^{a}	40^{a}	110^{ab}
PI-537668-BJ-1085-USA	7.90^{a}	11.40^{ab}	10.07^{a}	4.46^{a}	3.27^{b}	110^{a}	80^{a}	40^{a}	110^{ab}
PI-314650-Milutin-114	7.08^{c}	10.94^{b}	10.53^{a}	4.93^{a}	3.30^{b}	110^{a}	80^{a}	40^{a}	130^{a}
PI-306830-BJ-1632-India	7.19^{bc}	11.22^{ab}	10.39^{a}	4.99^{a}	3.26^{b}	110^{a}	80^{a}	50^{a}	110^{ab}
Significance	**	NS	NS	NS	*	NS	NS	NS	NS
LSD	0.49	1.76	2.48	1.03	0.31	44	30	10	30

Significance: *0.05, **0.01. Means with the same letter are not significantly different from each other. Means within columns were separated using the Least Significant Difference at P=0.05.

The nutrient contents of the seed meal of different safflower genotypes indicated that safflower seed meal can serve as an excellent animal feed. Safflower genotypes contained high seed meal dry matter, high protein, low fibers (NDF, ADF and ADL), moderate ash contents and acceptable mineral contents. In the context of livestock feed, dried animal feed with >85% DM content are regarded as high quality feed as they can have a longer shelf life without moulding (Van Saun, 2016). Therefore, as all the safflower genotypes under study had greater than 85% DM content proved that safflower meal can serve as an excellent and quality animal feed. The results of the current study are in agreement with results reported in literature (Hueze et al., 2012; Malakian et al., 2011). Heuze et al. (2012) researching in the nutritional composition of safflower meal and whole seed, reported that safflower meal obtained by expeller extraction contained 93.2% dry matter. Malakian et al. (2011) reported that safflower seeds contain about 94.4% DM.

The seed meal CP after oil extraction ranged between 19.3-22.5% depending on genotype, showing that safflower meal is an excellent source of protein for livestock feed especially ruminants and poultry; and it can be used for feed formulation and supplementation. The protein requirement for weaned calves, growing beef animals and finishing is reported to be 13.9, 13.5-15 CP and 12-14% CP, respectively, (NRC, 1996). In Australia, safflower seed and meal (seed meal after oil extraction) are fed to beef and dairy cattle, and sheep as feed supplement or mixed in feed rations (OGTR, 2015). In young sheep, supplementing poor quality diets with safflower meal resulted in increased weight gain and wool growth compared to a barley/urea supplement (OGTR, 2015). Research has shown safflower meal to be a valuable ingredient for dairy cows, with no noticeable effect on flavour or odour of milk produced, but improved the milk and meat quality due to high conjugated linoleic acid (CLA) in the milk and meat (Wood et al., 1999; Griinari and Bauman, 1999; Bottger et al., 2002; Mündel et al., 2004; Scholljegerdes et al., 2004; OGTR, 2015). Meat and milk high in CLA constitutes a health advantage to consumers (Griinari and Bauman, 1999).

The safflower seed meal NDF results suggested that the safflower seed meal was of medium quality for livestock feed (Van Soest et al., 1991; Van Saun, 2016; Ball et al., 2017). In the current study the safflower seed meal after oil extraction was obtained from hulled safflower seed and the oil extraction efficiency was 95% hence

explaining the medium NDF content of 54.6-61.2%. Dixon et al. (2003) reported that the seed cake NDF of safflower seed after oil extraction was 63.4% and was suitable as sheep feed. NRC (2001) reported that safflower meal contained 54.0% NDF. Similarly as in NDF, low levels of ADF are recommended because at high ADF levels digestibility of animal feed is decreased, thus as ADF levels increases, digestible energy levels decreases (Saha et al., 2013). Therefore, the results implied that PI 537668-BJ-1085-USA with 45.0% cake ADF was considered more digestible than other safflower genotypes due to its low ADF content. Alobeid et al. (2010) reported that safflower meal with medium protein (25%) has high fibre content (50% ADF).

Safflower meal ADL was reported at 18.0-20.8%, depending on the safflower genotype. The results implied that safflower meal have the potential to serve as animal feed. As lignin content in a feed increases, digestibility of cellulose decreases, thereby lowering the amount of energy potentially available to the animal (Saha et al., 2013). Moreover, at high ADL content, NDF and ADF contents are generally increased in an animal feed, thus reducing feed intake and digestibility of the feed, hence animal production and performance (Van Saun, 2016). Dixon et al. (2003) reported cake lignin of 15.5% in their experiment. Safflower meal ash content ranged between 1.10-1.60%, depending on the genotype, which was within the normal range for animal feed (Schroeder, 2012; Van Saun, 2016). The ash content of a seed/grain is expected to be within the range 1-4% on DM basis, for it to be rated as a quality animal feed (Schroeder, 2012; Van Saun, 2016).

Furthermore, the results of the study indicated that safflower meal have high quality mineral value which can be beneficial for animal feeding. NRC (1996) reported the mineral requirement of livestock to be between 0.25-0.30% P, 0.60-0.70% K, 0.50-0.60% Ca and 0.10% Mg, thus any feed providing these mineral compositions is regarded as a quality animal feed. Therefore, since the P, K, Ca, Mg and Na contents of the current study fell within these range, safflower meal was qualified as a potential quality animal feed. The sodium requirement of cattle is 0.07% for growing calves and dry cows, 0.10% for lactating cows (NRC, 2000). Goats and sheep needs 1.5 g/day and 0.06% Na contents, respectively (Wand, 2010). Mature sheep also require 0.11% Mg for normal growth and milk production (Wand, 2010). Exact Zn amount are not known for goat requirements, but between 10-60 ppm is considered satisfactory (NRC, 2000). Sheep require 36 ppm Zn in their diet (Wand, 2010). Fe requirements of livestock are 50 ppm for cattle, 30-75 ppm for sheep and goats. A daily intake of 750 ppm is considered acceptable for lactating goats (Wand, 2010; NRC, 2000). Sheep require 20-40 ppm of Mn in their diets (Wand, 2010). While the optimum quantity of Mn for poultry (chicken and turkeys) is about 50 ppm (Titus, 1934; Smith, 1996; Weiss, 2000). Copper toxicities can occur when dietary levels exceeding 100 ppm in cattle and 25 ppm in sheep (Ward, 2005). Safflower seed meal was reported to contain 181.19 mg/100g P, 6.8% K, 0.022% Ca, 0.35% Mg, 0.01-0.03% Na, 50 ppm Zn, 20 ppm Mn and 17.3 ppm Cu contents (USDH, 2010). Heuze et al. (2012) reported that safflower meal contained 0.67% P, 0.31% Mg. NRC (1996) reported that safflower seed meal contained 50 ppm Fe. Smith (1996) reported that safflower seed meal contained 20.4 ppm Mn.

4. Conclusion

Based on the nutritive content (DM, CP, NDF, ADF, ADL, macro-and micro minerals) of safflower seed meal (after oil extraction) of the nine safflower genotypes, it was concluded that safflower seed meal is an excellent sources of nutrients for livestock feed especially ruminants and poultry; and it can be used for feed formulation and supplementation.

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