Mineral profiles of agro-industrial by-products and locally available supplementary feeds and their implications for dairy cattle nutrition in Ethiopia

Fekede Feyissa[1], Getnet Assefa[2], Gezahegne Kebede[1] and Shiv Prasad[3]*

[1]Holetta Agricultural Research Center, P.O.Box 31, Holetta, Ethiopia
[2]Ethiopian Institute of Agricultural Research, P.O.Box 2003, Addis Ababa, Ethiopia
[3]National Dairy Research Institute, Karnal – 132 001 (Haryana), India
[*]Corresponding author: ffeyissa@yahoo.com

Abstract

This study assessed the macro- and trace mineral profiles of major agro-industrial by-products (AIBPs) and locally available feed resources commonly used as supplementary feeds to dairy cattle in Ethiopia. A total of 58 samples belonging to five categories of supplementary feeds (compound dairy rations/concentrates, oilseed cakes, wheat bran, middling and grains, brewery by-products, and pulse grain by-products) collected from different agro-industries and local sources were included in the study. The result showed considerable differences in mineral concentrations both within and among the different categories of supplementary feeds suggesting the likelihood of complementing a mineral or minerals deficient in some of the supplementary feeds/feed ingredients by using others. The concentration of most minerals measured in compound dairy rations lied within or above the ranges recommended in dairy cattle diets. On the other hand, average mineral profile of the other supplementary feed ingredients revealed deficiencies of two or more of the following elements: K, Mg, Na, P, S, Mn, and Zn for dairy cattle. Among the locally produced supplementary feed ingredients, oats grain and the traditional liquor residue (`Areke attela`) had exceptionally high Ca content. Mineral elements' variability noted in the different feed ingredients investigated in this study indicate the nutritional significance of combining various feed supplements in dairy ration formulation in order to rectify deficiencies of different minerals. Moreover, there is a need to demonstrate the comparative advantages of compound dairy ration to the individual concentrate feed ingredients in terms of cost and supply of the nutrients required by dairy cattle in order to promote its wider utilization in major dairy shed areas.

Key words: *macro-minerals, trace minerals, supplementary feeds, dairy cattle nutrition, Ethiopia*

Introduction

Livestock productivity in general and dairy productivity in particular is the function of nutrition, health status and genetic potential of the animal. Among these factors, nutrition plays the most important role as it represents the major cost of livestock production. A successful nutrition program requires proper balance of protein, energy, vitamins and minerals. Minerals are integral parts of nutrients required for growth and reproduction. In addition, mineral elements provide structural supports to the animal body, constituents of body fluids and serve as catalysts in both enzyme and hormone systems. In general, minerals fulfill several important functions for the maintenance of animal, growth and reproduction as well as health status. Hence, mineral inadequacies are the principal causes of reproductive failures and low production rates in dairy cattle (McDowell, 1985, 1997; Vergas and McDowell, 1997). However, in dairy cattle diets the emphasis given is skewed towards energy and protein sources with low consideration to mineral contents of the feeds. Due to this fact, mineral deficiencies and imbalances are likely to become more apparent and more critical in energy and protein rich feeds(Underwood and Suttle, 1999).In such situation cattle cannot perform to their full genetic potential unless their mineral needs are met, even if they receive 100% of their protein and energy requirements (Prasad *et al.,* 2007).

In Ethiopia, dairy cattle are mainly fed on natural pasture (grazing and/or hay), crop residues and different agro-industrial and locally available by-products as supplementary feeds. In the past, extensive studies have been carried out in the country to explore the nutritional limitations of such feeds to improved livestock production. However, most of the studies were mainly concentrated on the content and digestibility of major nutrients and not adequately addressed the aspects of mineral elements. Some studies (Kabaja and Little, 1988; Lemma and Smit, 2005 and Fekede *et al.,* 2013) have attested the low essential mineral element status of natural pastures and crop residues. On the other hand, studies on the mineral status of major agro-industrial and locally available by-products, feed resources that are widely utilized as supplement to dairy cattle, are very much limited. The work of Lemma and Smit (2005) on mineral composition of noug cake and grass pea haulm produced on Vertisols of the central highlands is one of the few documented information available in this regard. Knowledge on the mineral status of the different supplementary feed resources would help to identify the most deficient mineral elements in relation to the requirement of dairy cattle, which in turn would help to devise appropriate corrective measures. Therefore, this study was conducted to assess the important macro- and trace mineral profiles of major agro-industrial by-products and locally available supplementary feeds and their implications for dairy cattle nutrition in Ethiopia.

Materials and Methods

Collection of feed samples

Most of the feed ingredients commonly used as supplementary feeds to dairy cattle in Ethiopia constitute the by-products of different agro-industries (flour mills, oil mills and animal feed processors). Under smallholder farmers' conditions, different locally available/produced feeds such as local beverage by-products, oats grain, and different grains screenings and hulls are also used to supplement dairy cattle.

In the present study, a total of 58 samples belonging to different agro-industrial by-products and locally available feeds were collected to assess their mineral status. These feed categories more or less capture the supplements in common use by dairy cattle in the country. The categories of the different supplementary feeds, sources/locations and the number of samples collected for analysis are shown in Table 1.

Table 1. Types, number of samples and sources of the various supplementary feeds collected for mineral analysis

Category and types of supplementary feeds	No. of samples	Locations/sources
1. Compound dairy rations/concentrates		
1.1. Compound feed for lactating cows	4	Different animal feed processing plants in Addis Ababa and Bishoftu
1.2. Compound feed for pregnant cows	2	
1.3. Compound feed for heifers	2	
1.4. Compound feed for calves	2	
1.5. Compound feed for bulls	2	
2. Cereal grain mill by-products		
2.1. Wheat bran	5	Different flour and food processing factories in Addis Ababa, Bshoftu and Adama
2.2. Wheat middling	3	
2.3. Mixed grain screenings	2	Grain mills in Ejere
2.4. Oats grain	2	Holetta Research Center
3. Oil seed cakes and meals		
3.1. Noug (*Guizotia abyssinica*) seed cake	4	Different oil processing mills/factories at Modjo, Guder/Ambo, Addis Ababa and Ejere
3.2. Linseed cake	3	
3.3. Cotton seed cake	2	
3.4. Cotton seed meal	2	
4. Pulse hulls, screenings and bran		
4.1. Grass pea hull	3	Grain mills at Ejere
4.2. Field pea hull	3	
4.3. Field pea x Faba bean mixed hull	3	
4.4. Mixed pulses screenings	3	
4.5. Mixed pulses bran	3	
5. Local and industrial brewery residues		
5.1. `Areke Atela`	3	Local beverage producers in Holetta area
5.2. `Tela Atela`	3	
5.3. Industrial brewery residues	2	Meta Abo (Sebeta) & St. George (AA) breweries
Total number of samples	**58**	

Sample preparation and laboratory analysis

The samples were classified into five categories based on the nature and relative similarities of the supplementary feeds/by-products from which the samples were collected. This was purposively made for the sake of data analysis and result presentation and interpretations. The different categories included: compound ration, oil seed cakes, wheat bran, middling and grains, brewery residues (both industrial and local), and pulse hulls, screenings and bran. Upon proper drying (natural or using oven according to nature of the feed), the samples collected from the different categories of supplementary feeds were milled through a 1-mm sievesize for laboratory analysis. Analysis was made for a total of ten selected minerals including six macro-minerals (Ca, P, K, S, Na and Mg) and four trace minerals (Zn, Mn, Cu and Fe). For determination of both the macro- and trace minerals, the ground samples were dry ashed at 450°C for 4 hours in a furnace. The cooled ash was digested using 20%HNO_3 and then was filtered through a filter paper. In the filtrate, the P concentration was measured by spectrophotometer according to Murphy and Riley (1962). The concentrations of Ca, K, Mg, Na, Zn, Mn, Cu and Fe were analyzed using atomic absorption flame emission spectrometer Model AAS-6200 (Shimadzu Corp., Japan). Sulphur (S) was determined following the procedures described by Wolf (1982).Statistical Analysis System (SAS, 2002) was used for analyzing the data.

Results

Macro-minerals

The macro-mineral contents of the different AIBPs and locally produced supplementary feed resources were shown in Table 2.Significant variations ($p<0.05$) were observed in Ca, K and Mg contents among the different types of compound rations. The Ca content varied widely from 18.9 g/kg DM in bull ration to 82.6 g/kg DM in pregnant cows' ration, with a mean value of 48.3 g/kg DM. Following the pregnant cows` ration, higher Ca content was recorded in the ration of growing heifers which also had higher Na and Mg contents. Unlike Ca content, the other macro-minerals lied within relatively narrow range in the different compound rations. As opposed to Ca content, the P content was higher in bull ration than the other compound feeds. All the compound rations had low and almost similar S contents. In general, the overall average macro-mineral content of the compound dairy feeds evaluated in this study varied in the order Ca>K>Na>P>Mg>S.

Concentrations of the measured macro-minerals, except that of S and Na contents varied significantly ($p<0.05$) among the different oilseed cakes evaluated in the study. Noug cake had higher Ca and P contents ($p<0.05$) than the other oilseed cakes, while K, S and Mg contents were higher in cotton seed meal. Cotton seed cake also had better P, K and Mg contents, but relatively lower Ca and S contents. Relative to the other oilseed by-products, linseed cake had moderate concentrations of the measured macro-minerals. All the evaluated oilseed cakes had low and almost similar Na concentration and the overall mean macro-mineral contents of the different oilseed cakes varied in the order K>P>Ca>Mg>S>Na.

As shown in Table 2, the concentrations of the macro-minerals, except the S and Na contents showed significant variations ($p<0.05$) among the supplementary feeds categorized under bran, middling and grains/grain screenings. Oats grain had remarkably higher Ca content, while wheat bran, middling and mixed grains screenings were generally characterized by low Ca profile with the lowest concentration recorded in wheat middling. This shows that oats grain can be a good source of Ca for dairy cattle where it is available and used for feeding like the case of Selale area in the Ethiopian highlands. On the other hand, both wheat bran and wheat middling had comparably higher concentrations of P, K and Mg than oats grain ($p<0.05$). Mixed grains screenings also had comparable Mg content with that of wheat bran and middling. All the supplementary feeds in this category had very low and closely ranging S and Na contents.

Concentrations of the macro-minerals except Ca did not show significant variations (p>0.05) in the brewery by-products. The local liquor residue (`*Areke attela*`) had very high Ca content (p<0.05) than both the traditional brewery residue (`*Tela attela*`) and the industrial brewery residues, which had low and comparable Ca contents (6.9 vs 8.1 g/kg DM). On the other hand, comparatively higher P and S contents were recorded in the industrial brewery residue, while `*Tela attela*` had relatively higher concentrations of K, Na and Mg. Generally, the brewery by-products evaluated in this study were characterized by low concentrations of S, Na and Mg relative to the other macro-minerals.

Table 2. Macro-mineral profiles of different AIBPs and locally available supplementary feeds

Type and description of the supplementary feed	(g/kg DM)					
	Ca	P	K	S	Na	Mg
I. Compound ration						
Lactating cows ration	42.4[ab]	6.5	11.3[ab]	0.6	9.3	3.3[ab]
Pregnant cows ration	82.6[a]	6.9	12.9[a]	0.7	8.4	4.0[a]
Growing heifers ration	66.5[ab]	6.5	11.1[b]	0.7	11.0	4.1[a]
Calf ration	30.9[ab]	7.7	11.9[ab]	0.7	8.4	3.8[a]
Bull ration	18.9[b]	8.2	10.5[b]	0.6	9.1	2.4[b]
Mean±SE	***48.3±11.6***	***7.2±0.3***	***11.5±0.4***	***0.7±0.0***	***9.2±0.5***	***3.5±0.3***
II. Oilseed cakes						
Noug cake	8.0[a]	12.2[a]	13.1[ab]	1.4	0.4	4.1[b]
Linseed cake	6.9[ab]	7.2[b]	11.6[b]	1.5	0.5	4.0[b]
Cotton seed cake	4.6[b]	9.8[ab]	15.2[a]	1.2	0.5	4.5[a]
Cotton seed meal	5.3[ab]	11.6[a]	16.5[a]	1.9	0.5	4.5[a]
Mean±SE	***6.2±0.8***	***10.2±1.1***	***14.1±1.1***	***1.5±0.1***	***0.5±0.0***	***4.3±0.1***
III. Wheat bran, middling and grains						
Wheat bran	2.2[b]	11.4[a]	13.2[a]	0.6	0.5	2.8[a]
Wheat middling	0.5[b]	9.3[a]	12.2[a]	0.5	0.4	2.4[a]
Oats grain	56.5[a]	4.2[b]	5.3[b]	0.7	0.2	1.5[b]
Mixed grains screenings	2.5[b]	2.5[b]	3.8[b]	0.4	0.3	2.5[a]
Mean±SE	***15.4±13.7***	***6.9±2.1***	***8.6±2.4***	***0.6±0.1***	***0.4±0.1***	***2.3±0.3***
IV. Brewery residues (industrial and locally produced)						
Brewery residue	8.1[b]	6.0	0.7	1.1	0.3	1.9
Areke Attela*	44.2[a]	3.8	4.1	0.7	0.4	1.5
Tela Attela[@]	6.9[b]	4.5	6.5	0.9	0.7	2.0
Mean±SE	***19.7±12.2***	***4.8±0.6***	***3.8±1.7***	***0.9±0.1***	***0.5±0.1***	***1.8±0.2***
V. Pulse hulls, screenings and bran						
Grass pea hull	11.5[a]	1.8[c]	10.5[b]	0.3[c]	0.9[a]	2.3[a]
Field pea hull	4.1[e]	1.7[c]	7.8[d]	0.4[b]	0.6[c]	1.3[e]
Faba bean hull	7.0[c]	1.2[d]	8.3[c]	0.4[b]	0.7[b]	1.9[b]
Mixed pulses screenings	5.4[d]	4.7[a]	11.4[a]	0.8[a]	0.5[d]	1.7[c]
Mixed pulses bran	7.8[b]	3.2[b]	4.7[e]	0.4[b]	0.6[c]	1.6[d]
Mean±SE	***7.2±1.3***	***2.5±0.6***	***8.5±1.2***	***0.5±0.1***	***0.7±0.1***	***1.8±0.2***

[a-e]Mean values with different superscripts for each categories of supplementary feeds in a column differ significantly (p<0.05)

*- a traditional home-made liquor residue; [@]- a traditional home-made brewery residue

The result (Table 2) showed that concentrations of the macro-minerals varied significantly ($p<0.05$) among the different pulse hulls, pulse grain screenings and pulse bran evaluated in the study. Grass pea hull had significantly higher ($p<0.05$) Ca content followed by mixed pulses bran and faba bean hull, while field pea hull had lower concentration of Ca followed by mixed pulses grain screenings. The concentration of P was significantly higher ($p<0.05$) in mixed pulses grain screenings followed by mixed pulses bran, while the lowest P concentration was recorded in faba bean hull. On the other hand, both grass pea hull and field pea hull had closely comparable P contents. Mixed pulses grain screenings also had significantly higher ($p<0.05$) K content followed by grass pea hull and faba bean hull, while mixed pulses bran had lowest K content. All the pulse by-products generally had lower concentrations of S, Na and Mg. However, mixed pulses grain screenings had comparatively higher S content, while grass pea hull had higher concentrations of Na and Mg followed by faba bean hull.

This study also revealed considerable differences among the different categories of supplementary feeds in terms of average concentrations of the different macro-minerals. Compound rations had higher concentrations of Ca and Nathan the other supplementary feed resources. Oilseed cakes were found to be rich in most macro-minerals (P, K, S and Mg), but had lower Ca content as compared to the other supplementary feeds. Pulse hulls, pulse grain screenings and pulse bran had lower concentrations of P, S and Mg than the other supplementary feeds. Cereal (wheat) bran, middling and grain/grain screenings had lower Na content as compared to the other supplementary feed resources. Lower K and Mg contents were also observed in the brewery by-products than the other supplementary feeds evaluated in this study. In general, compound rations had higher concentration of Ca followed by brewery residues and wheat bran, middling and grains, while oilseed cakes were rich in P and K followed by compound rations.

Trace minerals

Table 3 shows the trace mineral contents of different AIBPs and locally available supplementary feed resources. Among the compound rations, bull ration had higher Zn content followed by growing heifers ration and lactating cows` ration, while calf ration and pregnant cows ration had comparatively lower Zn concentration. The concentration of Mn was significantly higher ($p<0.05$) in calf ration followed by bull ration and lactating cows ration, and was lower in pregnant cows ration. The concentration of Cu in compound rations varied in the order lactating cows ration>pregnant cows ration>bull ration>growing heifers ration>calf ration. The concentration of Fe was higher in pregnant cows ration followed by growing heifers ration and lactating cows` ration, while bull ration had relatively lower Fe content.

Concentrations of all the measured trace minerals showed significant variations ($p<0.05$) among the different oilseed cakes evaluated in the study. Linseed cake had significantly higher ($p<0.05$) Zn content followed by noug cake and cotton seed meal, while cotton seed cake had lower Zn concentration. On the other hand, noug cake had higher Mn concentration followed by linseed cake, while cotton seed cake and cotton seed meal had comparably lower Mn contents. The Cu content of the oilseed cakes varied in the order linseed cake>noug cake>cotton seed cake>cotton seed meal. Noug cake had considerably higher concentration of Fe followed by linseed cake, while cotton seed cake and cotton seed meal had lower Fe contents.

As shown in Table 3, concentrations of trace minerals also showed significant variations ($p<0.05$) among the supplementary feeds categorized under bran, middling and grains/grain screenings. Wheat bran had higher Zn content followed by wheat middling, while oats grain and mixed grains screenings had lower and very closer Zn contents. The concentration of Mn in this category of supplements also varied widely from as low as 27.1ppm in mixed grains screenings to as high as 113.4ppm in wheat middling. The Cu content was higher in wheat bran followed by mixed grains screenings and wheat middling, while oats grain had lower concentration of Cu. On the other hand, Fe content of these feed resources varied in the order mixed grains screenings>oats grain>wheat middling>wheat bran.

Among the brewery by-products evaluated in this study, the industrial brewery residue had higher Zn content followed by `*Areke attela*`, while `*Tela attela*` had relatively lower Zn content. On the other hand, the concentrations of both Mn and Fe were higher in `Tela attela` followed by `*Areke attela*`, and were lower in brewery residue. The concentration of Cu in these by-products varied in the order `*Areke attela*`>`*Tela attela*`>brewery residue.

The result (Table 3) showed significant variability in concentrations of trace minerals in the different pulse hulls, pulse grain screenings and pulse bran evaluated in the study ($p<0.05$). The Zn content varied from as low as 9.1ppm in faba bean hull to as high as 42.9ppm in mixed pulses screenings with a mean of 28.9ppm. The concentration of Mn varied in the order mixed pulses bran>grass pea hull>mixed pulses screenings>field pea hull>faba bean hull. Mixed pulses screenings had higher concentration of Cu followed by mixed pulses bran and faba bean hull, while grass pea hull and field pea hull had comparatively lower Cu contents. The concentration of Fe showed wide variability among the different pulse grain by-products and varied from as low as 94.8ppm in faba bean hull to as high as 454.2ppm in mixed pulses bran. It was generally noted that faba bean hull had lower concentrations of most of the measured trace minerals, while mixed pulses screenings and bran had comparatively higher levels of trace minerals.

As depicted in Table 3, average concentrations of trace minerals also showed considerable differences among the different categories of supplementary feeds evaluated in the study. The mean concentration of Zn varied in the order compound rations>brewery residues>wheat bran, middling and grains>oilseed cakes>pulse hulls, screenings and bran. Similarly, the mean Mn content was higher in compound rations followed by wheat bran, middling and grains and oilseed cakes, while brewery residues and pulse grain by-products had relatively lower concentration of Mn. Oilseed cakes had higher Cu content followed by brewery residues and compound rations, while wheat bran, middling and grains and pulse grain by-products had comparatively lower concentration of Cu. The average Fe concentration in the different supplementary feeds varied in the order oilseed cakes>compound rations>brewery residues>pulse hulls, screenings and bran>wheat bran, middling and grains. In general, compound rations were found to be rich in Zn and Mn, while oilseed cakes had higher concentrations of Cu and Fe among the different supplementary feeds evaluated in this study.

Table 3. Trace mineral profiles of different AIBPs and locally available supplementary feeds

Type and description of the supplementary feed	ppm			
	Zn	Mn	Cu	Fe
I. Compound ration				
Lactating cows ration	81.9	157.7[ab]	47.9	306.9
Pregnant cows ration	69.1	97.4[b]	45.6	488.2
Growing heifers ration	92.2	143.0[b]	32.1	376.3
Calf ration	72.9	222.1[a]	21.4	297.0
Bull ration	95.1	165.4[ab]	34.7	218.9
Mean±SE	***82.2±5.1***	***157.1±20.1***	***36.3±4.8***	***337.5±45.2***
II. Oilseed cakes				
Noug cake	46.6[ab]	113.2[a]	52.9[b]	962.4[a]
Linseed cake	57.5[a]	82.1[a]	92.5[a]	840.9[a]
Cotton seed cake	33.0[b]	20.4[b]	42.5[b]	134.7[b]
Cotton seed meal	41.4[ab]	21.1[b]	40.6[b]	80.4[b]
Mean±SE	***44.6±5.1***	***59.2±23.1***	***57.1±12.1***	***504.6±230.8***
III. Wheat bran, middling and grains				
Wheat bran	90.8[a]	105.9[a]	39.1[a]	69.0[c]
Wheat middling	69.1[b]	113.4[a]	23.8[ab]	132.4[b]
Oats grain	33.9[c]	45.6[b]	5.0[b]	145.3[b]
Mixed grains screenings	34.5[c]	27.1[c]	33.0[ab]	319.7[a]
Mean±SE	***57.1±13.9***	***73.0±21.5***	***25.2±7.4***	***166.6±53.7***
IV. Brewery residues (industrial and locally produced)				
Brewery residue	77.1	29.3[b]	31.2	264.2
Areke Attela*	50.9	32.0[b]	55.2	274.7
Tela Attela[@]	43.8	55.6[a]	49.3	408.1
Mean±SE	***57.3±10.1***	***39.0±8.4***	***45.2±7.2***	***315.7±46.3***
V. Pulse hulls, screenings and bran				
Grass pea hull	20.2[d]	43.9[b]	8.2[e]	258.2[c]
Field pea hull	31.4[c]	26.7[d]	12.1[d]	145.8[d]
Faba bean hull	9.1[e]	22.2[e]	26.5[c]	94.8[e]
Mixed pulses screenings	42.9[a]	39.5[c]	36.8[a]	417.4[b]
Mixed pulses bran	41.0[b]	60.5[a]	34.5[b]	454.2[a]
Mean±SE	***28.9±6.4***	***38.6±6.8***	***23.6±5.8***	***274.1±71.4***

[a-e]Mean values with different superscripts for each categories of supplementary feeds in a column differ significantly ($p<0.05$)
*- a traditional home-made liquor residue; [@]- a traditional home-made brewery residue

Discussion

The recommended concentrations of various minerals in diets for satisfactory nutrition of dairy cattle are documented in different editions of National Research Council (NRC, 1989, 2001). Table 4 shows the ranges and average concentrations of important macro and trace minerals in the different categories of supplementary feed resources evaluated in this study in comparison to the NRC recommendations for dairy cattle. It can be noted that compound rations had higher concentrations of Ca, Na, Mg, Mn, Cu and Fe than the levels recommended in dairy cattle diets. On the other hand, the concentrations of P, K and Zn in the compound rations did closely match with the NRC recommendations, while the S content lied below the recommended levels for satisfactory nutrition of dairy cattle. However, except the Ca content average concentrations of the other minerals measured in compound rations in the present study were lower than the maximum tolerable concentrations in the diets of dairy cattle (NRC, 1989, 2001). The observed high level of Ca in the compound rations may indicate the high emphasis given by feed processors to include more sources of Ca while formulating the compound feeds. Nevertheless, feed processing plants who have been engaged in the preparation of compound rations should have information on the recommended levels of different minerals for optimum nutrition of dairy cattle and opt to fix proportions of the different feed ingredients accordingly. This not only helps to avoid using a variety of costly ingredients with no apparent justification, but also enables to prevent diseases and reproductive disorders which may occur as a result of mineral imbalances in the diet.

Relative to the Ca content, average concentration of P in the compound rations evaluated in this study was low resulting in wider Ca:P ratio (on average 6.7:1). Calcium and Phosphorous are closely related and laid down in bone in a ratio of 2.2 parts Ca to 1 part P. This implies that a deficiency or an overabundance of either mineral could interfere with the proper utilization of the other, as an imbalance of either mineral can cause them to bind with each other and become unavailable to the animal (Harris *et al*., 2003). Although, it is generally recommended that diets of livestock should have Ca:P ratio of about 1:1 to 2:1 (Underwood, 1981), livestock can tolerate dietary Ca:P ratios of more than 10:1 without any serious effect provided the P intake is adequate (Ternouth, 1990). Wider Ca:P ratios, however, are detrimental in feeds apparently deficient in P (Wan Zahari *et al.,* 1990). As the P content of the compound rations evaluated in the current study fall within the recommended range for dairy cattle, the observed wider Ca:P ratio may not have undesirable consequences to dairy animals fed on these feeds. In general, the compound rations evaluated in this study could fulfill the requirement of dairy cattle for most of the important minerals as per the NRC recommendations except S. This suggests that feeding dairy cattle using these feeds is essential for addressing the requirement of dairy animals with regard to mineral nutrition. However, studies have revealed that compound rations were rarely used by smallholder peri-urban dairy farmers in selected milk shed areas (Ejere, Sululta and Girar-Jarso)in the central highlands of Ethiopia (Fekede, 2013). According to the sample dairy farmers in the study areas, unlike the other feed ingredients such as wheat bran, compound rations were not readily available in the local market. Moreover, the farmers did not have adequate knowledge on comparative advantages of compound rations in terms of both cost and feeding value. This was further witnessed by the compound feed processors who indicated that they usually supply their product to large scale commercial/urban dairy farms based on pre-requested demand. This suggests the need to promote the use of compound rations especially by improved dairy producers including the smallholder systems while demonstrating their comparative advantage to the individual feed ingredients in terms of cost and supply of nutrients required by dairy cattle.

The average concentrations of Ca, P, K and Mn in the oilseed cakes evaluated in this study fall closer to and/or within the ranges recommended for satisfactory nutrition of dairy cattle (NRC, 1989, 2001). On the other hand, Mg, Cu and Fe contents of the oilseed cakes lie above the recommended ranges, while S, Na and Zn fall below the ranges recommended for satisfactory nutrition of dairy cattle indicating the need to consider supplementations with other sources of these minerals when oilseed cakes are used as supplementary feeds to dairy cattle. However, the average concentrations of all the minerals in the oilseed cakes were lower than the maximum tolerable levels of the respective minerals in the diets of dairy cattle.

Wheat bran, middling and mixed grains screenings had very marginal Ca contents relative to NRC recommendations in dairy cattle diet, while the concentration of Ca in oats grain was higher than the maximum tolerable concentration in the diets of dairy cattle. On the other hand, wheat bran and middling had higher contents of P, K and Mg which can meet the requirements of dairy cattle as compared to oats grain. In view of this, mixing ground oats grain with wheat bran while feeding dairy cattle where applicable could be a suitable strategy to meet the requirement of dairy cattle for Ca, P, K and Mg. This may also help to correct the Ca:P ratio to the desirable range. The average concentrations of S and Na in wheat bran, middling, oats grain and mixed grains screenings evaluated in this study were lower than the recommended ranges in dairy cattle diets (NRC, 1989, 2001) suggesting the need for supplementations with sources of these minerals. Relative to the NRC recommendations, wheat bran and middling could meet the requirement of dairy cattle for all the trace minerals (Zn, Mn, Cu and Fe) measured in this study, while oats grain and mixed grains screenings had lower Zn and Mn contents than the NRC recommendations. Moreover, oats grain had much lower Cu content than the range recommended for satisfactory nutrition of dairy cattle.

Among the brewery by-products evaluated in this study, the local liquor residue (`Areke attela`) had much higher Ca content than the maximum tolerable concentration, while the P content of all the brewery by-products was fairly within the range recommended in dairy cattle diets (NRC, 1989, 2001). On the other hand, concentrations of the other macro-minerals (K, S, Na and Mg) in the brewery by-products lied below the recommended levels in the diets of dairy cattle. The Cu and Fe contents of the brewery by-products lied above the NRC recommendations in dairy cattle diets, but lower than the maximum tolerable concentrations (NRC, 1989, 2001). The concentration of Zn in the industrial brewery residue and the Mn content in the traditional home-made brewery residue (`*Tela attela*`) lied within the recommended levels of the minerals in dairy cattle diets. Relative to the NRC recommendations in dairy cattle diets (NRC, 1989, 2001), `*Areke attela*` and `*Tela attela*` were deficient in Zn, and the industrial brewery residue and `*Areke attela*` were deficient in Mn contents.

The average concentrations of P, K, S, Na and Mn in pulse grain by-products evaluated in this study lied below, while the average Ca content lied within the range recommended for satisfactory nutrition of dairy cattle (NRC, 1989, 2001). Grass pea hull, faba bean hull and mixed pulses bran had relatively high Ca content which can meet the requirement of dairy cattle as per the NRC recommendation. Moreover, the concentration of K recorded in grass pea hull and mixed pulses screenings lied within the ranges recommended in dairy cattle diets. The Mg content recorded in grass pea hull and faba bean hull could also meet the requirement of dairy cattle. Among the trace minerals measured in pulse grain by-products, Cu and Fe could meet the dietary requirement of dairy cattle, while the mean Zn and Mn levels were relatively lower than the NRC recommendations. However, the concentration of Mn recorded in mixed pulses bran could meet the requirement of dairy cattle.

Conclusions and Implications

Mineral contents showed considerable differences both within and among the different categories of supplementary feeds evaluated in this study. This difference is vital as it helps to single out the potential feed ingredients that are likely be used to address mineral deficiencies or to exploit complimentary feed resources for a given situation. Though limited in availability and utilization, the compound rations evaluated in the study could fulfill the requirement of dairy cattle for most of the important minerals. Hence, promotion of these feeds in major dairy shed areas where productive cows are raised could be vital to address mineral deficiencies. Average mineral profiles of the other supplementary feed ingredients revealed deficiencies of S, Na and Zn in oilseed cakes; S and Na in wheat bran, middling and cereal grain/grain by-products; K, S, Na and Mg in brewery by-products, and P, K, S, Na, Mg, Zn and Mn in pulse grain by-products relative to the levels recommended in dairy cattle diets. Among the locally available supplementary feeds, oats grain and the traditional liquor residue *(`Areke attela`)* had exceptionally high Ca content and help to rectify Ca deficiency when used in mixture with low Ca deficient feed ingredients such as wheat bran and middling. In general, the different supplementary feeds evaluated in this study had excess of some minerals, optimum quantity of some minerals and deficient in some other minerals relative to the levels recommended in dairy cattle diets. Therefore, feeding dairy cattle using a compound ration composed of the different feed ingredients could help to meet mineral requirements of the dairy animal via exploitation of complementarities of mineral concentrations in the different ingredients.

Table 4. Comparison of mineral contents of the different supplementary feed resources with NRC recommendations for satisfactory nutrition of dairy cattle

Mineral	NRC recommendation	Range and average concentration of minerals in the different supplementary feeds evaluated in this study				
		Compound rations	Oilseed cakes	Wheat bran, middling and grains	Brewery by-products	Pulse grain by-products
g/kg DM						
Ca	7-11 (20)	18.9-82.6, 48.3*	4.6-8, 6.2*	0.5-56.5, 15.4*	6.9-44.2, 19.7*	4.1-11.7, 7.2*
P	4-9 (10)	6.5-8.2, 7.2*	7.2-12.2, 10.2*	2.5-11.4, 6.9*	3.8-6, 4.8*	1.2-4.7, 2.5*
K	9-14 (30)	10.5-12.9, 11.5*	11.6-16.5, 14.1*	3.8-13.2, 8.6*	0.7-6.5, 3.8*	4.7-11.4, 8.5*
S	2.0-2.5	0.6-0.7, 0.7*	1.2-1.9, 1.5*	0.4-0.7, 0.6*	0.7-1.1, 0.9*	0.3-0.8, 0.5*
Na	1.8-4.5	8.4-11, 9.2*	0.4-0.5, 0.5*	0.2-0.5, 0.4*	0.3-0.7, 0.5*	0.5-0.9, 0.7*
Mg	2.0-2.5 (5)	2.4-4.1, 3.5*	4-4.5, 4.3*	1.5-2.8, 2.3*	1.5-2, 1.8*	1.3-2.3, 1.8*
mg/kg DM						
Zn	70-80 (500)	69.1-95.1, 82.2*	33-57.5, 44.6*	33.9-90.8, 57.1*	43.8-77.1, 57.3*	9.1-42.9, 28.9*
Mn	50-60 (1000)	97.4-222.1, 157.1*	20.4-113.2, 59.2*	27.1-113.4, 73*	29.3-55.6, 39*	22.2-60.5, 38.6*
Cu	12-30 (100)	21.4-47.9, 36.3*	40.6-92.5, 57.1*	5-39.1, 25.2*	31.2-55.2, 45.2*	8.2-36.8, 23.6*
Fe	50-100 (1000)	218.9-488.2, 337.5*	80.4-962.4, 504.6*	69-319.7, 166.6*	264.2-408.1, 315.7*	94.8-454.2, 274.1*

Figures in the brackets indicate the maximum tolerable concentrations of minerals in dairy cattle diet (NRC, 1989, 2001)
*Indicate mean values

Acknowledgements

This study was funded by Ethiopian Institute of Agricultural Research and laboratory analytical service was provided by the soil research program of Holetta Research Center.

References

Fekede Feyissa, Seyoum Bediye, Getnet Assefa and Shiv Prasad. 2013. Effects of harvesting stage, storage system and storage duration on mineral composition of natural pasture hay at Holetta, central highlands of Ethiopia. *Eth. J. Anim. Prod. 13(1) – 2013: 121 –138.* ©Ethiopian Society of Animal Production (ESAP) EJAP ISSN: 1607–3835 Volume 13, Number 1, 2013.

Fekede Feyissa. 2013. Evaluation of feed resources and assessment of feeding management practices and productivity of dairy cattle in the central highlands of Ethiopia. PhD Thesis submitted to National Dairy Research Institute, Karnal-132001 (Haryana), India.

Harris, B.Jr., Adams, A.L., Van Horn, H.H., 2003. Mineral Needs of Dairy Cattle. Dairy Science Department, Cooperative Extension Service, Institute of food and Agricultural Sciences, University of Florida, Gainesville. http://edis.ifas.ufl.edu. Retrieved 04 December 2012.

Kabaija, E., Little, D.A., 1988. Nutrient qualities of forages in Ethiopia with particular reference to mineral elements. In: Dzowela, B.H. (ed). ILCA, Addis Ababa. *Proc. of the 3rd pasture network in eastern and southern Africa workshop on African Forage Genetic Resources, evaluation of forage germplasm and extensive livestock production systems*, 27-30 April 1987, Arusha, Tanzania.

Lemma, G. and Smit, G.N., 2005. Crude protein and mineral composition of major crop residues and supplemental feeds produced on Vertisols of the Ethiopian highland. *Anim. Feed Sci. Technol*., 119, 143-153.

McDowell, L. R. 1985. Nutrition of Grazing Ruminants in Warm Climates. Academic Press, New York, p. 443.

McDowell, L. R. 1997. Minerals for Grazing Ruminants in Tropical Regions. Extension Bulletin, Animal Science Department, Centre for Tropical Agriculture, University of Florida. 81.

NRC, 1989. Nutrient requirements of dairy cattle, 6th ed. National Academy Press, Washington, DC.

NRC, 2001. Nutrient requirements of dairy cattle, 7th revised ed. National Academy Press, Washington, DC.

Prasad, C. S., Gowda N. K. S.,and Pal D.*T*., 2007.Implications for minerals deficiency in ruminants and methods for its amelioration. In Bakshi, M. P. S. and Wadhwa, M. (eds) Proceedings of International Tropical Animal Nutrition Conference Volume I Invited papers .Pp.152-162.

SAS, 2002. Statistical Analysis System, version 9.0, SAS Institute, Inc., Cary, NC, USA.

Ternouth, J.H., 1990. Phosphorus and beef production in northern Australia. 3. Phosphorus in cattle-a review. Tropical Grasses 24:159-69.

Underwood, E.J. and Suttle, N.F.,1999. The Mineral Nutrition of Livestock. 3rd Edition, CABI Publishing, London, UK.

Underwood, E.J., 1981.The Mineral Nutrition of Livestock. Commonwealth Agricultural Bureaux, London.

Vargas, E. and McDowell, L. R. 1997. Mineral Deficiencies of Cattle in Central America and the Caribbean, Emphasizing Cost Rica. Proceedings of the International Conference of

Livestock in the Tropics, University of Florida, Gainesville, Florida, May, Gainesville, Florida, 1997, 99-114.

Wan Zahari, M., Thompson, J.K., Scott, D., Buchan,W., 1990. The dietary requirements of calcium and phosphorus for growing lambs. Anim. Prod. 50, 301–308.