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Nutritional Qualities of Agro-Industrial By-Products and Local Supplementary Feeds for Dairy Cattle Feeding

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አህፅርኦት

ይህ ጥናት በኢትዮጲያ ውስጥ ለወተት ከብቶች በድጎማ መኖነት የሚውሉ ዋና ዋና የተረፈ-ግብርና ኢንዱስትሪ እና አርሶ-አደሮች በየአባቢያቸው በተለምዶ ለድጎማ መኖነት የሚጠቀሙባቸው የድጎማ መኖዎች የመኖ ጥራትን ያካተት ነው፡፡ ለጥናቱም በተለያዩ የድጎማ መኖ ዓይነቶች (የወተት ከብቶች ምጥን የድጎማ መኖዎች፣ የምግብ ዘይት ጭማቂ ተረፈ-ምርቶች፣ የስንዴ ፉርሽካና ፉርሽኬሎ፣ የተለያዩ የብርዕና ጥራጥሬ ተረፈ-እህል መኖዎችና በባህላዊና ዘመናዊ አልኮሆል መጥመቂያ ፋብሪካዎች የሚገኙ ተረፈ-ምርት መኖዎች) የሚመደቡ በድምሩ 58 የሚሆኑ የድጎማ መኖ ናሙናዎች በአዲስ አበባና በዙሪያዉ ከሚገኙ አግሮ-ኢንዱስትሪዎች፣ የመኖ ማቀነባበሪያና ማደራጃ ፋብሪካዎችና የወተት ከብት አርቢዎች ተሰብስበዋል፡፡ የመኖዎቹን ጥራት ለማወቅም የናሙናዎቹ የድርቆ፣ የአጠቃላይ ማዕድን ይዘት፣ የአልሚ ንጥረ-ነገር ይዘት፣ እንዲሁም የተለያዩ የጭረት ዓይነቶች ይዘትና የአፈጨጫጨት መጠናቸው በሆለታ ግብርና ምርምር የእንስሳት ሥነ-ምግብ ቤቱ-ሙከራ ተተንትነዋል፡፡ በዚህም መሠረት የድጎማ መኖዎቹ ከተመደቡባቸው ንዑሳን ክፍሎች አንጻር በመኖ ጥራት ደረጃቸው የተለያዩ መሆናቸውን ($p<0.05$) ጥናቱ አመላክቷል፡፡ የአልሚ ንጥረ-ነገር ይዘትን በተመለከት፤ የጥጃ ምጥን መኖ-ከተለያዩ የወተት ከብቶች ምጥን መኖዎች፣ የጥጥ ፍሬ ፋጉሎ-ከምግብ ዘይት ጭማቂ ፋጉሎዎች፣ የስንዴ ፉርሽኬሎ-ከዱቄት ፋብሪካ ተረፈ-ምርቶች፣ ዘመናዊ የቢራ ፋብሪካ ጭማቂ-ከልክሆል ተረፈ-ምርቶች እንዲሁም ቅይጥ የጥራጥሬ ብጣሪ መኖዎች ከጥራጥሬ ብጣሪ ተረፈ መኖዎች የተሻሉ መሆናቸውን ለማረጋገጥ ተችሏል፡፡ በሌላ በኩል የድጎማ መኖዎቹ ከተመደቡበት ዓበይት የመኖ ክፍሎች አኳያ ሲወዳደሩ አማካይ የአልሚ ንጥረ-ነገር ይዘት ደረጃቸው እንደሚከተለዉ ይሆናል፡- የዘይት መጭመቂያ ተረፈ-ምርቶች (310.4 ግራም/በኪ.ግ የድርቆ ይዘት) > የአልክሆል ፋብሪካ ተረፈ-ምርቶች > የወተት ከብቶች ምጥን መኖዎች > የጥራጥሬ እህሎች ተረፈ-ምርት (ብጣሪ) መኖዎች > የብርዕና አገዳ እህሎች ተረፈ-ምርት (ብጣሪ) መኖዎች (139.2ግራም/በኪ.ግ የድርቆ ይዘት)፡፡ በአማካይ የNDF ጭረት ይዘታቸው የድጎማ መኖዎቹን የጥራት ደረጃ ከተመደቡበት ዓቤይት የመኖ ክፍሎች አንፃር የአልኮሆል ፋብሪካ ተረፈ-ምርት መኖዎች (577.7 ግራም/በኪ.ግ የድርቆ ይዘት) > የጥራጥሬ እህሎች ተረፈ-ምርት (ብጣሪ) መኖዎች > የወተት ከብቶች ምጥን መኖዎች > ፋጉሎዎች > የብርዕና አገዳ እህሎች ተረፈ-ምርት (ብጣሪ) መኖዎች (250.2 ግራም/በኪ.ግ የድርቆ ይዘት) እንደሆነ ጥናቱ አሳይቷል፡፡ በአማካይ የADF የጭረት መጠናቸው በአቤይት የመኖ ክፍሎች የተመደቡት መኖዎች የጥራት ደረጃቸውን በተመለከተ የጥራጥሬ እህሎች ተረፈ-ምርት (ብጣሪ) መኖዎች (327.8 ግራም/በኪ.ግ የድርቆ ይዘት) > የአልክሆል ፋብሪካ ተረፈ-ምርት መኖዎች > ፋጉሎዎች > የወተት ከብቶች ምጥን መኖዎች > የብርዕና አገዳ እህሎች ተረፈ-ምርት (ብጣሪ) መኖዎች (92.0 ግራም/በኪ.ግ የድርቆ ይዘት) እንደሆነ ከጥናቱ ለማወቅ ተችሏል፡፡ አማካይ የሊግኒን የጭረት መጠንን በተመለከተ፡- ፋጉሎዎች (79.5 ግራም/በኪ.ግ የድርቆ ይዘት) > የአልክሆል ፋብሪካ ተረፈ-ምርት መኖዎች > የጥራጥሬ እህሎች ተረፈ-ምርት (ብጣሪ) መኖዎች > የወተት ከብቶች ምጥን መኖዎች > የብርዕና አገዳ እህሎች ተረፈ-ምርት (ብጣሪ) መኖዎች (20.9 ግራም/በኪ.ግ የድርቆ ይዘት) መሆኑን የጥናቱ ዉጤት ያሳያል፡፡ የድጎማ መኖዎቹ ካሉበት ዓቤይት የመኖ ክፍሎች አኳያ በላብራቶሪ አፈጫጨት መጠናቸዉ ሲነፃፀሩ የጥራት ደረጃቸዉ፡- የብርና አገዳ እህሎች ተረፈ-ምርት (ብጣሪ) መኖዎች (763.3 ግራም/በኪ.ግ የድርቆ ይዘት) > የወተት ከብቶች ምጥን መኖዎች > ፋጉሎዎች > የአልክሆል ፋብሪካ ተረፈ-ምርት መኖዎች > የጥራጥሬ እህሎች ተረፈ-ምርት (ብጣሪ) መኖዎች (537.5 ግራም/በኪ.ግ የድርቆ ይዘት) መሆኑን ለመረዳት ተችሏል፡፡ ጠቅልል ባለ መልኩ ከጥናቱ ዉጤት የፋጉሎና አልክሆል ፋብሪካ ተረፈ-ምርት የድጎማ መኖዎች በአሜሪካ ብሄራዊ የምርምር ካውንስል (NRC) በመጀመሪያ የአለባ ወቅት ለታላቢ የወተት ላሞች ከሚያስፈልገዉ በላይ በከፍተኛ የአልሚ ንጥረ-ነገር ይዘት የበለጸጉ መሆናቸውንና በተቃራኒዉ ደግሞ የብርዕና አገዳ እንዲሁም የጥራጥሬ እህሎች ተረፈ-ምርት (ብጣሪ) የድጎማ መኖዎች በላቸው የአልሚ ንጥረ-ነገር ይዘት (17-19%) በተመሳሳይ የአለባ ወቅት ላይ የሚገኙ የታላቢ ላሞችን ፍላጎት ማሟላት እንደማይችሉና በሌሎች የአልሚ ድጎማ መኖዎች መታገዝ እንዳለባቸው ለማወቅ ተችሏል፡፡ በሌላ መልኩ የወተት ከብቶች ምጥን የድጎማ መኖ በአልሚ የንጥረ-ነገር ይዘቱ የአሜሪካ ብሄራዊ ምርምር ካውንስል (NRC) ለወተት ከብቶች የእርባታ ፍላጎት ካስቀመጠው መጠን ጋር ተቀራራቢ እንደሆነ ለማወቅ ተችሏል፡፡

Abstract

This study assessed the nutritional qualities 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 viz., compound dairy rations/concentrates, oilseed cakes, wheat bran, middling and grains, *brewery by-products, and pulse grain by-products collected from different agro-industries located in and around Addis Ababa and local sources were included in the study. The feed samples were analyzed for chemical contents (DM, Ash, CP, NDF, ADF, Lignin, and in-vitro organic matter digestibility (IVOMD) at Holetta Agricultural Research Center Animal nutrition laboratory. Contents of the various nutritional parameters showed significant variations ($p<0.05$) among sub-groups within the different categories of supplementary feeds. The important nutritional parameter, CP content, was higher in calf ration among the compound dairy feeds, in cotton seed cake among the oilseed cakes, in wheat middling among the cereal grain by-products, in industrial brewery residue among the brewery by-products, and in mixed pulses screenings among the pulse grain by-products. The result also revealed considerable differences among the different categories of supplementary feeds in average values of the important nutritional parameters. Accordingly, the average CP content varied in the order: oilseed cakes (310.4g/kg DM)>brewery by-products>compound dairy ration>pulse grain by-products>cereal grain by-products (139.2g/kg DM). The mean NDF content varied in the order: brewery by-products (577.7g/kg DM)>pulse grain by-products>compound dairy ration>oilseed cakes>cereal grain by-products (250.2g/kg DM). The average ADF content varied in the order: pulse grain by-products (327.8g/kg DM)>brewery by-products>oilseed cakes>compound dairy ration>cereal grain by-products (92.0g/kg DM). The average lignin content also varied in the order: oilseed cakes (79.5g/kg DM)>brewery by-products>pulse grain by-products>compound dairy ration>cereal grain by-products (20.9g/kg DM). The mean IVOMD varied in the order: cereal grain by-products (763.3g/kg DM)>compound dairy ration>oilseed cakes>brewery by-products>pulse grain by-products (537.5g/kg DM). It was generally observed that oilseed cakes and brewery by-products had higher, while cereal grain by-products and pulse grain by-products had lower CP contents than the range (17-19%) recommended by NRC in the rations of lactating dairy cows during the early lactation stage. On the other hand, the average CP content recorded in compound dairy rations was comparable with the NRC recommendations in dairy cattle diets.*

Introduction

The supply of processed animal feedstuffs is very limited in Ethiopia. According to CSA, 2012, only about 11 animal feed manufacturers are operating in the country. Moreover, majority of them are working below their designated production potentials owning to several reasons including: low supply of raw materials, lack of commercial orientations by the farmers, poor awareness about processed feeds utilization by livestock producers, lack of tax exemptions and double taxations for individual feed ingredients in the compound feed mixtures (Adugna, 2009). Consequently, most feed processing plants are primarily producing for their own consumptions with very limited supply to the market. Study by Birhanu *et al*. (2009) indicated that only five manufacturers that are congregated in and around Addis Ababa were producing feed for sale with an average annual feed production of about 8,997 metric tons. In views of the emerging market-oriented livestock production (improved dairying, fattening, etc) in the country and the corresponding supplementary feed requirement, it is obvious that the supply of processed feedstuffs in the country fall short of the anticipated demand. Studies in selected milk shed areas (Ejere, Sululta and Girar-Jarso) in the central highlands of Ethiopia revealed that compound feeds were rarely accessed and used by smallholder peri-urban dairy farmers (Fekede, 2013). This was further witnessed by the compound feed processors who indicated that they usually supply their product to few commercial dairy farms based on request.

As a result, supplementation of dairy cattle in the urban and peri-urban smallholder dairy production systems in the highlands of the country is mainly based on individual feed ingredients produced as by-products of flour and oil processing industries, and different locally available by-products. This is because they are relatively easily accessible to farmers and some non-conventional by-products are also available for feeding at comparatively lower prices than manufactured feeds (Grasser *et al.*, 1995). Availability of supplementary feeds (both conventional and non-conventional types) per se is not the only challenge to the development of livestock industry in general and the dairy industry in particular, but also quality of the feeds is equally important. Various research reports have been documented on nutritional profiles of different AIBPs and locally available supplementary feed resources in the country (Seyoum and Fekede 2008; Adugna 2008; Seyoum *et al.,* 2007; Tegene *et al.,* 2009; Tadesse *et al.,* 2009; Ajebu 2010). However, qualities of these feed resources are highly dynamic and subjected to variations depending on the type of raw material, processing method, season, handling, storage, transportation, and utilization. This necessitates periodical assessment and laboratory analysis to generate up-to-date information on nutritional qualities of the feeds, which in turn helps to sensitize farmers and the concerned institutions in charge of monitoring and regulating qualities of feedstuffs in relation to the standards set for the different groups/species of animals in the country. Therefore, this study was conducted to assess the important nutritional 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 feeds used for supplementary feeding of dairy cattle in Ethiopia constitute the by-products of different agro-industries including flourmills, oil mills, industrial brewery and sugar factories. Moreover, smallholder dairy farmers use different locally available/produced feeds such as local beverage by-products, oats grain, and different grain screenings and hulls as supplementary feeds to dairy cattle. Fifty-eight samples of conventional and non-conventional feed types which were reported to be dominantly used as supplementary feeds to dairy cattle in the country were collected from the different agro-industries, compound feed processors and small-scale flour and oil mills in and around major cities in the Addis Ababa milk shed. The categories of the different supplementary feeds, sources/locations and the number of samples collected for analysis are shown in Table 1.

Table 1. The 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	Compound feed manufacturing plants in Addis Ababa and Bishoftu (4 in No)
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. Bran, middling & other cereal grain mill by-products		
2.1. Wheat bran	5	Flour and food processing factories in Addis Ababa, Bshoftu and Adama (5 in No)
2.2. Wheat middling	3	
2.3. Mixed grain screenings	2	Grain mills in Ejere (2 in No)
2.4. Oats grain	2	Holetta Research Center
3. Oilseed cakes and meals		
3.1. Noug (*Guizotia abyssinica*) seed cake	4	Oil processing mills/factories at Modjo, Guder/Ambo, Addis Ababa and Ejere (5 in No)
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 (3 in No)
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 sieve size for laboratory analysis. Samples were analyzed for dry matter (DM) (over-dried at 105°C overnight) and total ash using method 924.05 of AOAC (1990). The Kjeldahl wet digestion procedure (AOAC, 1999; method 954.01) was used to determine the total N content. The crude protein (CP) content was then estimated by multiplying the Kjeldahl N by 6.25. The structural plant constituents, NDF, ADF and Lignin were determined according to the standard procedures (ADF: AOAC, 1995, no. 973.18, expressed without residual ash after incineration at 500°C for 1h; lignin: Robertson and Van Soest, 1981, determined by solubilization of cellulose with sulphuric acid; NDF: Mertens (2002), analyzed with heat stable amylase and expressed without residual ash).

The IVOMD was determined according to the two-stage rumen fluid technique described by Tilley and Terry (1963). Rumen fluid was obtained from three rumen-cannulated Zebu x Holstein crossbred steers fed on a basal diet of native grass hay and supplemented with 2kg concentrate. The same natural pasture used in this study was the source of the hay fed to the donor animals. Metabolizable Energy (ME) content was estimated from IVOMD according to MAFF (1984):

$$ME\ (MJ/kg\ DM) = 0.015*IVOMD\ (g/kg\ DM)$$

Results and Discussions

The chemical compositions and nutritive values of different categories of AIBPs and locally available supplementary feeds used for feeding dairy cattle in Ethiopia are described below:

Compound dairy feeds/rations

The chemical composition and *in-vitro* digestibility of compound dairy feeds evaluated in the present study are shown in Table 2.

Table 2: Chemical composition and *in-vitro* digestibility of commercially produced compound dairy feeds

Parameter	Type of the compound feed					*Mean±SE*
	Lactating cows ration	Pregnant cows ration	Growing heifers ration	Calf ration	Bull ration	
DM (g/kg)	888.9[b]	897.5[a]	895.3[ab]	890.5[ab]	891.9[ab]	*892.8±1.6*
(g/kg DM)						
Ash	92.5[b]	133.7[a]	86.3[b]	84.6[b]	104.1[b]	*100.2±9.0*
CP	190.8[ab]	177.2[c]	188.2[abc]	198.5[a]	184.6[bc]	*187.9±3.5*
NDF	407.9[d]	404.9[d]	465.2[b]	440.3[c]	482.4[a]	*440.1±15.3*
ADF	142.8[c]	151.8[bc]	158.6[ab]	165.8[a]	164.9[a]	*156.8±4.3*
Lignin	30.1[c]	28.5[c]	50.6[b]	53.6[ab]	54.8[a]	*43.5±5.9*
IVOMD	702.8[a]	626.6[b]	659.6[ab]	688.5[a]	672.6[a]	*670.0±13.1*
ME (MJ/kg DM)	10.6[a]	9.4[b]	9.9[ab]	10.3[a]	10.1[ab]	*10.1±0.2*

[a-e]*Mean values with different superscripts in a row differ significantly (p<0.05)*

Among the compound rations, pregnant cows ration had significantly higher ($p<0.05$) DM content, while lower DM content was recorded in the ration of lactating cows. The average DM content of the different types of compound rations was 892.8 g/kg and narrowly varied from 888.9 g/kg in lactating cows ration to 897.5 g/kg in pregnant cows' ration. Significantly ($p<0.05$) higher ash content was also obtained in pregnant cows ration, while no significant variation was observed in ash contents of the other types of compound rations ($p>0.05$). The ash contents of the compound rations was found to vary from 84.6 g/kg DM in calf ration to 133.7 g/kg DM in pregnant cows ration, with an average of 100.2 g/kg DM. The fiber fractions (NDF, ADF and lignin) also showed significant variations ($p<0.05$) in the different types of compound rations. The NDF content varied from as low as 404.9 g/kg DM in pregnant cows ration to as high as 482.4 g/kg DM in bull ration, with an average of 440.1 g/kg DM. The mean ADF content of the compound rations was 156.8 g/kg DM and ranged from 142.8 g/kg DM in lactating cows ration to 165.8 g/kg DM in the calf ration. The lignin content also varied from 28.5 g/kg DM in pregnant cows ration to 54.8 g/kg DM in bull ration, with an average of 43.5 g/kg DM.

Significant variations ($P<0.05$) were also noted among the different types of compound rations in CP content, IVOMD and ME content (Table 2). The mean CP content was 187.9 g/kg DM and varied from 177.2 g/kg DM in pregnant cows ration to 198.5 g/kg DM in calf ration. The IVOMD varied from 626.6 g/kg DM in pregnant cows ration to 702.8 g/kg DM in lactating cows ration, with a mean of 670 g/kg DM. Similarly, the ME content varied from 9.4 MJ/kg DM in pregnant cows ration to 10.6 MJ/kg DM in the ration of lactating cows, with a mean value of 10.1 MJ/kg DM.

According to the contacted feed processing plants, the main ingredients used for preparing compound dairy ration were maize; noug cake/cotton seed cake/soya bean cake based on availability, wheat bran, wheat middling, limestone and salt. Although much documented information is not available on nutritional qualities of the different types of compound dairy rations in Ethiopia, Seyoum *et al.*, (2007) reported higher figures than the current values recorded for all the nutritional parameters in the ration of lactating dairy cows. Moreover, comparatively higher DM, CP and ME contents than the present figures were reported in commercial dairy ration (Yoseph *et al.*, 2003). Different factors such as the types and proportions of ingredients used, environmental and management factors (like efficiency and technological levels of the processing plants), and the number of samples considered for analysis may be the potential reasons for the observed variations in nutritional qualities of the compound rations.

According to the feeding guidelines and nutrient requirements of dairy cows published by National Research Council (NRC, 2001), the ration of lactating dairy cows should contain 17-19, 15-16, and 13-15% CP on DM basis, respectively during the early, mid and late lactations. The recommended concentration of NDF in the ration of lactating cows was 30-34, 30-38, and 33-43% of the DM during the early, mid and late lactations, respectively. Similarly, the recommended ADF content in the lactating cows ration was 19-21, 19-23, and 22-26% of the DM, respectively during the early, mid and late lactations (NRC, 2001). The CP content recorded in lactating cows ration in the present study was comparable to the NRC recommendations. On the other hand, the NDF content in this study fall above, while the ADF content was lower than the NRC recommendations in the ration of lactating dairy cows. Under the Ethiopian context, the practice of ration formulation according to lactation stage of the cow is uncommon and hence is not possible to relate with the NRC recommendations during the different stages of lactation.

Oilseed cakes

The different oilseed cakes evaluated in this study showed significant ($p<0.05$) variations in all the measured nutritional parameters (Table 3).

Table 3: Chemical composition and *in-vitro* digestibility of selected oilseed cakes

	Type of the oilseed cake				
Parameter	Noug cake	Linseed cake	Cotton seed cake	Cotton seed meal	*Mean±SE*
DM (g/kg)	920.7[b]	916.1[b]	948.6[a]	917.1[b]	*925.6±7.7*
g/kg DM					
Ash	104.0[a]	80.2[b]	59.6[d]	74.0[c]	*79.5±9.3*
CP	285.4[c]	285.7[c]	312.8[b]	357.6[a]	*310.4±17*
NDF	357.9[b]	362.1[b]	383.2[a]	362.9[b]	*366.5±5.7*
ADF	298.3[a]	283.9[b]	147.6[d]	169.1[c]	*224.7±38.7*
Lignin	111.3[a]	103.1[a]	50.8[b]	52.6[b]	*79.5±16.1*
IVOMD	638.4[b]	721.4[a]	604.3[b]	690.0[a]	*663.5±26.1*
ME (MJ/kg DM)	9.6[b]	10.9[a]	9.1[b]	10.4[a]	*10.0±0.4*

[a-d]*Mean values with different superscripts in a row differ significantly ($p<0.05$)*

The DM content of the oilseed cakes ranged from 916.1 g/kg in linseed cake to 948.6 g/kg in cotton seed cake, with an average figure of 925.6 g/kg. The mean ash content of the oil seed cakes was 79.5 g/kg DM and varied from 59.6 g/kg DM in cotton seed cake to 104 g/kg DM in noug cake. The NDF content ranged narrowly from 357.9 g/kg DM in noug cake to 383.2 g/kg DM in cotton seed cake, with a mean of 366.5 g/kg DM. The mean ADF content of the oilseed cakes was 224.7 g/kg DM and ranged from 147.6 g/kg DM in cotton seed cake to 298.3 g/kg DM in noug cake. Moreover, lower lignin content (50.8 g/kg DM) was recorded in cotton seed cake and higher lignin content (111.3 g/kg DM) in noug cake, with the average figure of 79.5 g/kg DM. The CP content of the oilseed cakes was on average 310.4 g/kg DM and varied from 285.4 g/kg DM in noug cake to 357.6 g/kg DM in cotton seed cake. The IVOMD of the oilseed cakes varied from 604.3 g/kg DM in cotton seed cake to 721.4 g/kg DM in linseed cake, with a mean of 663.5 g/kg DM. Likewise, the ME content varied from 9.1 MJ/kg DM in cotton seed cake to 10.9 MJ/kg DM in linseed cake, with a mean figure of 10 MJ/kg DM.

The chemical composition and nutritive values of the oilseed cakes in the present study lied within the ranges reported for protein supplements under Ethiopian condition (Seyoum *et al*., 2007). Adugna (2008) also reported CP content ranging from 28-35% in most oilseed cakes which was in agreement with the current observation. The DM, ash and CP contents recorded for noug cake in this study were comparatively lower, while the fiber fractions (NDF, ADF and lignin) were higher than the figures reported by different authors (Seyoum *et al*., 2007; Solomon, 2007; Zewdie *et al*., 2010 and Kasahun *et al*., 2012). The IVOMD and ME contents of noug cake noted in the current study were comparable to the values reported by Seyoum *et al.,* (2007), but lower than the figure reported by Zewdie *et al.,* (2010). Adugna (2008) also reported lower NDF content and IVOMD, but higher lignin and CP contents in noug cake produced by the solvent extraction method than the present figures. In cotton seed cake, values higher than the present figures were reported for the ash, NDF, ADF and lignin contents (seyoum *et al*., 2007; Zewdie *et al*., 2010). The CP content recorded for cotton seed cake in the present study was higher than the figure reported by Seyoum *et al*. (2007), but lower than the figures reported by other authors (Adugna, 2008; Zewdie *et al.*, 2010 and Kasahun *et al*., 2012). The IVOMD values documented by Seyoum *et al.,* (2007) and Zewdie *et al.,* (2010) in cotton seed cake were comparable with the present figures, while higher value than the current figure was reported by Adugna (2008). In the case of linseed cake, the ash and lignin contents recorded in the present study were higher, while NDF, ADF, IVOMD and ME contents were lower than the figures reported by Seyoum *et al.,* (2007). The CP content of linseed cake observed in this study was comparable with the values given by Seyoum *et al.,* (2007) and Adugna (2008), but was lower than the figure reported by Kasahun *et al.,* (2012).

The type of the oilseed, the method, and efficiency of extracting oil from the seeds, other management, and environmental conditions could be the potential reasons for the observed variations in chemical compositions of oilseed cakes. For instance, according to Adugna (2008), oilseed cakes produced by mechanical extraction of the oil from the seeds contained more fat and fiber and less protein than those produced by solvent (chemical) extraction. The high temperature and pressure of the expeller extraction may denature the protein in the oilseed cake and reduce its digestibility, particularly degradability in the rumen.

Flour industry by-products and cereal gains/grain screenings

Table 4 shows chemical compositions and *in-vitro* digestibility of flourmill by-products (wheat bran, middling), oats grain, and mixed grains screenings. The measured nutritional parameters showed significant variations ($p<0.05$) among the different by-products.

Table 4: Chemical composition and *in-vitro* digestibility of flour industry by-products and cereal gain/grain screenings

Parameter	Type of feed (by-product) Wheat bran	Wheat middling	Oats grain	Mixed grains screenings	*Mean±SE*
DM (g/kg)	886.4^{b}	885.3^{b}	922.3^{a}	908.2^{ab}	*900.6±9.0*
g/kg DM					
Ash	49.9^{a}	49.0^{a}	39.2^{b}	30.4^{c}	*42.1±4.6*
CP	158.3^{a}	167.1^{a}	136.3^{b}	95.1^{c}	*139.2±16.1*
NDF	471.3^{a}	403.0^{b}	64.3^{c}	62.1^{c}	*250.2±108.8*
ADF	146.7^{a}	140.4^{a}	40.6^{b}	40.3^{b}	*92.0±29.8*
Lignin	39.6^{a}	34.1^{b}	7.8^{c}	2.2^{d}	*20.9±9.3*
IVOMD	711.5^{c}	734.0^{bc}	780.3^{ab}	828.6^{a}	*763.6±26.0*
ME (MJ/kg DM)	10.7^{c}	11.1^{bc}	11.7^{ab}	12.4^{a}	*11.5±0.4*

$^{a-d}$*Mean values with different superscripts in a row differ significantly (p<0.05)*

The mean DM content of wheat bran, middling, and grains was about 900.6 g/kg and ranged from 885.3 g/kg in wheat middling to 922.3 g/kg in oats grain. The ash content ranged from 30.4 g/kg DM in mixed grains screenings to 49.9 g/kg DM in wheat bran, with a mean of 42.1 g/kg DM. The NDF content ranged widely from as low as 62.1 g/kg DM in mixed grains screenings to as high as 471.3 g/kg DM in wheat bran, with an average value of 250.2 g/kg DM. Similarly, the ADF content varied from 40.3 g/kg DM in mixed grains screenings to 146.7 g/kg DM in wheat bran, with a mean of about 92 g/kg DM. The lignin content was also much lower (2.2 g/kg DM) in mixed grains screenings and higher (39.6 g/kg DM) in wheat bran, with a mean of 20.9 g/kg DM. The CP content of wheat bran, middling and grains/grain screenings was on average 139.2 g/kg DM and varied from 95.1 g/kg DM in mixed grains screenings to 167.1 g/kg DM in wheat middling. The IVOMD of these categories of supplements was found to be higher and varied from 711.5 g/kg DM in wheat bran to 828.6 g/kg DM in mixed grains screenings, with a mean of 763.6 g/kg DM. The ME content also varied from 10.7 MJ/kg DM in wheat bran to 12.4 MJ/kg DM in mixed grains screenings, with an average figure of 11.5 MJ/kg DM. Generally, wheat bran, middling, and grains/grain screenings evaluated in this study had chemical compositions and nutritive values within the ranges reported for energy supplements under the Ethiopian condition (Seyoum *et al.*, 2007). For wheat bran, comparable ash contents to the present figure, higher NDF, CP, IVOMD and ME contents, but lower ADF content than the current observation have been reported (Seyoum *et al.*, 2007; Zewdie *et al.*, 2010). Higher CP contents than the present figure were also reported (Adugna, 2008; Kasahun *et al.*, 2012) for wheat bran. Moreover, Adugna (2008) reported higher ash content, but lower NDF and lignin contents than the figures recorded for wheat bran in this study. Higher DM, NDF, CP, IVOMD and ME contents, and lower ash, ADF and lignin contents than the present figures were reported for wheat middling (Seyoum *et al.*, 2007). Similarly, Adugna (2008) reported higher DM, NDF and CP contents, but values comparable with the present observation in ash and lignin contents for wheat middling. Moreover, wheat middling contains higher proportion of germ and flour remnants than wheat bran (fibrous and flaky product), and consequently has lower fiber contents, but higher CP content and IVOMD than wheat bran.

Brewery by-products

The chemical compositions and *in-vitro* digestibility of brewery residues (both industrial brewery residue and the by-products of local alcoholic beverages) showed significant variations ($p<0.05$) as shown in Table 5.

Table 5: Chemical composition and *in-vitro* digestibility of industrial and locally produced brewery by-products

Parameter	Type of by-product			*Mean±SE*
	Brewery residue	\`Areke Atela\`*	\`Tela Atela\`@	
DM (g/kg)	956.2^b	966.8^a	954.0^b	*959.0±4.0*
g/kg DM				
Ash	43.4^a	25.4^b	47.3^a	*38.7±6.7*
CP	237.8^a	182.3^b	211.8^{ab}	*210.6±16.0*
NDF	633.8^a	541.7^c	557.5^b	*577.7±28.4*
ADF	292.6^a	219.9^b	221.9^b	*244.8±23.9*
Lignin	76.4^b	77.7^{ab}	78.2^a	*77.4±0.5*
IVOMD	584.5^c	674.0^a	613.9^b	*624.1±26.3*
ME (MJ/kg DM)	8.8^c	10.1^a	9.2^b	*9.4±0.4*

$^{a-c}$*Mean values with different superscripts in a row differ significantly ($p<0.05$)*
**- a traditional home-made liquor residue; @- a traditional home-made brewery residue*

The local liquor by-product (\`Areke atela\`) had higher DM content, while both the industrial brewery residue and traditional brewery residue (\`Tela atela\`) had comparable DM contents. The mean DM content of the brewery residues was 959 g/kg and varied from 954 g/kg in \`Tela atela\` to 966.8 g/kg in \`Areke atela\`. The higher DM content in \`Areke atela\` may be attributed to the removal of high amount of moisture during the distillation and filtration processes of extracting the liquor. The ash content of the brewery by-products varied from 25.4 g/kg DM in \`Areke atela\` to 47.3 g/kg DM in \`Tela atela\`, with an average of 38.7 g/kg DM. The mean NDF content was 577.7 g/kg DM and varied from 541.7 g/kg DM in \`Areke atela\` to 633.8 g/kg DM in the industrial brewery residue. Likewise, the ADF content varied from 219.9 g/kg DM in \`Areke atela\` to 292.6 g/kg DM in the industrial brewery residue, with a mean of about 244.8 g/kg DM. On the other hand, the three brewery by-products had very closer lignin contents. The brewery residues had higher CP contents (210.6 g/kg DM on average) and varied from 182.3 g/kg DM in \`Areke atela\` to 237.8 g/kg DM in the industrial brewery residue. The average IVOMD of these feed supplements was 624.1 g/kg DM and varied from 584.5 g/kg DM in the industrial brewery residue to 674 g/kg DM in \`Areke atela\`. The mean ME content was 9.4 MJ/kg DM and also varied from 8.8 MJ/kg DM in the industrial brewery residue to 10.1 MJ/kg DM in \`Areke atela\`.

Previous studies on nutritional profiles of brewery by-products indicated lower DM, ash, NDF, ADF and CP contents, but higher IVOMD and ME contents than the current observation in the industrial brewery residue (Seyoum *et al.*, 2007). Zewdie *et al.,* (2010) also reported lower DM content, but higher contents of the other nutritional parameters than the values currently recorded in brewery residue. Closely comparable CP content with the present figure, but lower DM, NDF, ADF and lignin, and higher ash content were also reported in brewery residue from Bedele brewery (Solomon, 2007). Similarly, Kasahun *et al.,* (2012) reported lower DM and higher ash contents, but comparable CP content with the present figure in brewery grain sampled from Meta-Abo and St. George breweries, where the current samplings were also done. Lower NDF and lignin contents, but comparable CP and ME contents to the present figures were also reported in brewery dried grain (Adugna, 2008).

The CP content of `Areke atela` recorded in this study was slightly higher than the figures (176 and 178g/kg DM) reported by Kasahun *et al.,* (2012) and Adugna (2008), respectively, while the IVOMD was lower than the value reported by Adugna (2008). On the other hand, higher NDF and lignin contents were found in `Areke atela` than the figures reported by Adugna (2008). The CP content recorded for `Tela atela` in the current study was comparable with the figures reported by different authors (218 g/kg DM: Solomon, 2007; 202 g/kg DM: Adugna, 2008; 210 g/kg DM: Zewdie *et al.*, 2010), but higher than the figure (164 g/kg DM) reported by Kasahun *et al.,* (2012). Solomon (2007) and Zewdie (2010) reported higher, while Kasahun *et al.,* (2012) reported lower ash contents in `Tela atela` than the present figure. The NDF contents reported by Solomon (2007) and Adugna (2008) in `Tela atela` were lower, while the value reported by Zewdie *et al.,* (2010) was higher than the figure obtained in the present study. On the other hand, higher ADF and lignin contents were reported for `Tela atela` than the current observation (Solomon, 2007; Adugna, 2008; Zewdie *et al.*, 2010). The observed variations in nutritional qualities of the local brewery by-products could be attributed to differences in the types and varieties of crops used for making the traditional beverages, and other management and environmental factors.

Pulse hulls, bran and grain screenings

Significant variations ($p<0.05$) were also observed in chemical compositions and *in-vitro* digestibility of different pulse grain by-products reported to be used as other locally available supplementary feeds to dairy cattle in the highlands of Ethiopia (Table 6).

Table 6: Chemical composition and *in-vitro* digestibility of different pulse grain by-products

Parameter	Type of the by-product					*Mean±SE*
	Grass pea hull	Field pea hull	Faba bean hull	Mixed pulses screenings	Mixed pulses bran	
DM (g/kg)	941.7^{a}	936.2^{c}	932.7^{d}	926.5^{e}	937.0^{b}	*934.8±2.5*
g/kg DM						
Ash	43.4^{b}	32.3^{d}	29.5^{e}	52.6^{a}	41.1^{c}	*39.8±4.1*
CP	135.1^{c}	112.4^{d}	68.0^{e}	302.6^{a}	206.3^{b}	*164.9±41.1*
NDF	515.3^{c}	539.1^{a}	519.8^{b}	393.5^{e}	452.1^{d}	*484.0±26.9*
ADF	337.8^{a}	321.9^{d}	320.7^{e}	334.6^{b}	323.8^{c}	*327.8±3.5*
Lignin	66.6^{a}	59.2^{b}	58.7^{c}	50.9^{e}	54.5^{d}	*58.0±2.6*
IVOMD	453.2^{c}	361.4^{d}	336.2^{e}	833.5^{a}	703.2^{b}	*537.5±98.4*
ME (MJ/kg DM)	6.8^{c}	5.5^{d}	5.1^{e}	12.5^{a}	10.6^{b}	*8.1±1.5*

$^{a-e}$*Mean values with different superscripts in a row differ significantly (p<0.05)*

The average DM content of these feeds was found to be 934.8 g/kg and varied from 926.5 g/kg in mixed pulses screenings to 941.7 g/kg in grass pea hull. The mean ash content varied from 29.5 g/kg DM in faba bean hull to 52.6 g/kg DM in mixed pulses screenings. The NDF content of the different pulse grain by-products varied widely from as low as 393.5 g/kg DM in mixed pulses grains screenings to as high as 539.1 g/kg DM in field pea hull, with a mean of 484 g/kg DM. The mean ADF content of these supplements was estimated to be 327.8 g/kg DM and varied from 320.7 g/kg DM in faba bean hull to 337.8 g/kg DM in grass pea hull. The lignin content also varied from 50.9 g/kg DM in mixed pulses grains screenings to 66.6 g/kg DM in grass pea hull, with an average of 58 g/kg DM. The average CP content of pulse hulls, screenings and bran was estimated to be 164.9 g/kg DM and widely varied from as low as 68 g/kg DM in faba bean hull to as high as 302.6 g/kg DM in mixed pulses grains screenings. Similarly, the IVOMD of these feed supplements varied from as low as 336.2 g/kg DM in faba bean hull to as high as 833.5 g/kg DM in mixed pulses grains screenings, with a mean of 537.5 g/kg DM. The ME content also varied from 5.2 MJ/kg DM in faba bean hull to 12.5 MJ/kg DM in mixed pulses grains screenings, with a mean of 8.1 MJ/kg DM.

The values recorded for Ash, NDF, ADF, Lignin and CP contents in grass pea in the present study were lower than the figures reported by Berhane (2013). However, the ash and CP contents reported by Kasahun *et al.* (2012) in grass pea were comparable with the current figures. Similarly, Zewdie *et al.,* (2010) and Berhane (2013) reported higher Ash, NDF, ADF and CP contents than the values obtained in this study for field pea hull. Seyoum *et al.* (2007) also reported higher values than the current figures in most nutritional parameters (Ash, NDF, ADF, CP, IVOMD and ME contents), but lower lignin content than the present value for faba bean hull. Likewise, Kasahun *et al*. (2012) reported higher ash and CP contents than the figures currently observed for faba bean hull.

This study also revealed marked differences among the different categories of supplementary feed resources in terms of average values of the different nutritional parameters. The mean NDF content varied in the order: brewery by-products>pulse hulls, screenings, and bran>compound dairy ration>oilseed cakes>wheat bran, middling, and grains/grain screenings. The average ADF content varied in the order: pulse hulls, screenings, and bran>brewery by-products>oilseed cakes>compound dairy ration>wheat bran, middling, and grains/grain screenings. The average lignin content varied in the order: oilseed cakes>brewery by-products>pulse hulls, screenings, and bran>compound dairy ration>wheat bran, middling, and grains/grain screenings. The mean CP content also varied in the order: oilseed cakes>brewery by-products>compound dairy ration>pulse hulls, screenings, and bran>wheat bran, middling, and grains/grain screenings. Both the average IVOMD and ME contents varied in the order: bran, middling and grains/grain screenings>compound dairy ration>oilseed cakes>brewery by-products>pulse hulls, screenings and bran.

Conclusions

The compound dairy rations evaluated in this study can sufficiently meet at least the CP and energy requirement of dairy cattle according to the feeding standards recommended for tropical cattle and their crosses with European breeds and the values are comparable with NRC recommendations. Oilseed cakes and brewery by-products had higher, while cereal grain and pulse grain by-products had lower CP contents than the range (17-19%) recommended in the rations of lactating dairy cows during the early stage of lactation. Hence, feeding a ration formulated from the different ingredients could be more useful to meet the nutrient requirement of dairy cattle than using the individual feed ingredients. This enables to exploit the difference in nutritional qualities among the various feed ingredients and helps to complement a nutrient or nutrients deficient in some supplementary feeds/feed ingredients by using others. Locally produced non-conventional feed supplements such the local alcoholic beverage residues and grain by-products could also help to reduce cost of milk production by reducing over dependency on the costly feed supplements. However, feeding trials and animal response studies are required to generate further information on the biological and economic advantages of using rations formulated from locally available ingredients over the industrially manufactured feeds.

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