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Short communication

NUTRIENT COMPOSITION, VOLATILE FATTY ACIDS PRODUCTION, DIGESTIBLE ORGANIC MATTER AND ANTI-NUTRTIONAL FACTORS OF SOME AGRO-INDUSTRIAL BY-PRODUCTS OF ETHIOPIA

Tegene Negesse

Department of Animal and Range Sciences, Hawassa University, PO Box 5
Hawassa, Ethiopia. E-mail: sgsdean@yahoo.com

ABSTRACT: Nutrients, metabolizable energy (ME), anti-nutritional factors, digestible organic matter (DOM) and volatile fatty acids (VFA) production of 17 agro-industrial by-products from Ethiopia were determined. Highest amount of ash was found in fishmeal (FM) and of lignin in sisal waste (SW) and banana peels (BP). Cabbage leftover (CL), onion peels (OnP), papaya peels (PaP) and FM had high CP (137 to 490 g/kg DM) and NPN (51 to 141 g CP/kg DM); distillery by-product (DB) and brewery by-product (BB) had high CP (179 and 187 g/kg DM) and NDF (535 and 396 g/kg DM, respectively) but low NPN (21 and 9 g CP/kg DM). CL, OnP, PaP and FM had low NDF (< 240 g/kg DM). Because of high NDF and lignin, BB and coffee parchment (CPa) had low DOM (507±30 and 322±4 g/kg DM, respectively). CPa and SW had low ME (<6.6±0.3 MJ/kg DM) and DOM (<568±15 g/kg DM); the rest had high ME (7.7 to 13.6 MJ/kg DM) and DOM (>576±9 g/kg DM) except avocado peels (AP) and BB. VFA concentrations were >19.1±1.8 mM except in CPa, FM and AP (<12.1±2.9 mM). Coffee pulp (CPu), CL and MP had high total phenolics (123 to 151 g/kg DM) and tannin (42 to 86 g/kg DM). BP had largest amount of phytate. Hemolytic activity (saponin) was detected in FM, potato peels, SW, CPa and CL. The feeds can serve as sources of energy and protein.

Key words: Agro-industrial by-products, antinutrional factors, metabolizable energy, nutritive value, digestible organic matter

INTRODUCTION

Appropriate use of relatively inexpensive feeds is of paramount importance for profitable livestock production. However, expensive conventional livestock feedstuffs frequently demand consideration of use of by-product. Efficient use of by-products relies on their chemical and physical properties.

In all developing countries including Ethiopia, grains which form the bulk of concentrate feeds for animals are in short supply and expensive, because the importance and use of grains as human food has progressively increased which causes the livestock industry to compete with humans for this resource.

The use of non-conventional feedstuffs to decrease competition for food between humans and animals will reduce feed cost and contribute to self-sufficiency. It is imperative to look for cheaper non-conventional feed resources that can complement available forages. Potential feedstuffs include fish offal, duckweed and kitchen leftovers (potato peel, carrot peel, onion peel and cabbage leftover), chicken feather, blood, poultry litter, algae/Spirulina, Leucaena leaf, local brewery and distillery by-products, sisal waste, gut content, cactus, coffee parchment and coffee pulp which are commonly found in many places in Ethiopia and could be valuable feed resources. The nutrient content, including organic matter digestibility and antinutritional factors of these feedstuffs need to be evaluated before these byproducts can be effectively used in animal nutrition.

This study reports potential availability, chemical composition, contents of antinutritional factors, digestible organic matter and metabolizable energy contents for 17 agro-industrial by-products.

Abbreviations: ADF, acid detergent fiber; AP, avocado peel; BB, brewery by-product; BP, banana peel; CaP, carrot peel; CL, cabbage leftover; CP, crude protein; CPa, coffee parchment; CPu, coffee pulp; CT, condensed tannin; DB, distillery by-product; DM, dry matter; DOM, digestible organic matter; EE, ether extract; FM, fishmeal; ME, metabolizable energy; MP, mango peel; NDF, neutral detergent fiber; NPN, non protein N; NTP, non-tannin phenolics; OnP, onion peel; OrP, orange peel; P, phytate; PaP, papaya peel; PBS, phosphate buffer solution; PiP, pineapple peel; PoP, potato peel; S, saponin; TP, total phenolics; TT, total tannin; VFA, volatile fatty acid; SW, sisal waste.

MATERIALS AND METHODS

Sampling sites

Fish offal for the preparation of meals were collected from Lake Hawassa; vegetable peels from Hawassa University cafeterias and fruit peels from hotels (Hawassa); sisal waste from sisal industry (Hawassa); brewery and distillery by-products from households with traditional brewery and distillery (Hawassa); coffee hull and pulp from coffee cherry processing units in Sidama (south Ethiopia).

Collection and processing of samples

Samples of sisal waste were taken from different batches of the waste produced by the Sisal Factory and collected in plastic bags, sun-dried, ground to pass 1 mm sieve size and stored in airtight plastic bag. Samples of brewery and distillery by-products were taken from two volunteer women who are engaged in traditional brewing and distilling. The brewery and distillery by-products were collected separately in plastic cans (20 liters) with screw caps. After thorough mixing the DM was measured at 105°C and the rest were sun-dried, ground and stored as above. The parchment and pulp were taken together from dry processed cherry and further separated by hand and ground without sun drying. The peels and leftover were collected separately, sun-dried, ground and stored in similar ways as other feeds.

In Ethiopia vegetable peels and cabbage leftover are inevitably produced because peeled vegetables are not available on the market. A large amount of potential animal feed is wasted in the preparation of food in the parts that are discarded because of being unfit for human consumption. Large quantities of these by-products can be collected wherever there is large scale food preparation, such as university cafeterias, hospitals and hotels.

Potato, onion and carrot peels and cabbage leftover were collected from 3 different cafeterias at Hawassa University. To minimize spoilage peels and leftovers were collected immediately after peeling. They were pooled by type, chopped using scissors and knives. DM content of fresh samples (initial DM) was determined at 105°C and the rest of the samples were sun-dried, ground and stored as above. The ratios between peel and whole fruit were determined by measuring the weights before and after peeling.

Fruit peel from mango, avocado, papaya, pineapple, banana and orange were collected separately from volunteer hotels that were producing juice in their kitchen. Peels of each fruit were then pooled and processed like vegetable peels. Seeds of avocado, mango, papaya and orange were not included in peels. Avocado peel could not be ground and pass through 1 mm sieve because of high fat content and therefore 2 mm was used. For most of the analyses, fat-free sample of avocado peel was used. The ratio between peel and whole fruit were determined by measuring weights before and after peeling.

The offal includes gut, head, skin, scale, eyes, gills and gonads of tilapia, catfish and barb, except the head of tilapia that was used for soup making. The offal was cooked in a rectangular sheet metal, 65 cm × 65 cm × 85 cm; open at the top; with a 40 cm stand; and with two outlets (for oil and water) positioned at 5 cm and 50 cm from the bottom of the cooking vessel was used. Twenty liters of water was added to the bowl and heated with firewood. When the water started boiling (90 to 95°C), the offal was transferred to the bowl, cooked for 17 min and stirred gently at an interval of 3 min. The floating oil and water was gently removed after 20 min of cooling. The cooked offal was then thinly and evenly spread on blue plastic sheet, sun dried for 10 to 12 days and stirred three times daily. It was protected from flies with mesh wire. Drying was stopped when a constant weight of the sample was obtained and ground and stored as above.

In vitro *studies*

The feed samples (200 mg DM) were incubated in 30 ml buffered rumen liquor in triplicates and were repeated on three separate days (Menke *et al.*, 1979). Rumen fluid was taken into pre-warmed CO_2 filled thermos flasks taken before offering the morning feed from two rumen-cannulated, non-pregnant, non-lactating Holstein Friesian cows (kept exclusively on medium quality diet) and then mixed. It was strained using a nylon bag with pore size of 100 μm. All handling was carried out with continuous flushing by CO_2. The rumen fluid was added to buffered mineral solution, which was maintained in a water bath at 39°C and mixed with magnetic stirrer. Buffered rumen fluid (30 ml) was dispensed into each syringe containing the feed samples (200 mg DM, syringes were kept in the water bath overnight to condition the feed) and put back into the water bath at 39°C. Three syringes containing 30 ml inoculum served as blanks. Gas production at 24h was standardized using the Hohenheim hay standard. Digestible organic matter (DOM) and metabolizable energy (ME) were calculated according to Menke *et al.* (1979). After 24 hours of incubation suitable aliquots from the syringes were transferred to Eppendorf vials and stored in a freezer until they were analyzed for VFA.

Chemical analyses

Chemical analyses were conducted in duplicates at Hohenheim University, Germany. The proximate composition of the feeds was determined (AOAC, 1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin were determined according to Van Soest *et al.* (1991). NDF was assayed without heat stable amylase and both NDF and ADF were expressed inclusive of residual ash. Lignin was determined by solubilization of cellulose with 72% sulphuric acid.

Volatile fatty acids (VFA) were analyzed (Höltershinken *et al.*, 1997). After gas volume was measured after 24 h of incubation of feed samples, about 1ml of homogenized aliquots were pipetted into a 1.5 ml Eppendorf cup kept on ice to immediately stop the fermentation process. They were then centrifuged (30,000 g, 4°C for 10 min). To 630 µl of the supernatant transferred to fresh vials, 70 µl of internal standard (1 ml methylvaleric acid and 99 ml formic acid) was added and kept at 4°C overnight to precipitate soluble proteins. After centrifugation (10,000 g and 4°C for 10 min), 500 µl of the supernatant was transferred to a 1.5 ml glass vial, sealed with serum cup and read in a Gas Chromatograph.

Total phenolics and total tannins were determined by spectrophotometric method according to Makkar *et al.* (1993b). Tannins were quantified as the difference between phenolics before and after tannin removal from the extract using polyvinyl pyrrolidone. Condensed tannins were measured with butanol-HCl- Fe^{3+} reagent (Porter *et al*., 1986). Total phenols and tannins were expressed as tannic acid equivalent and condensed tannins as leucocyanidin equivalent.

Phytate was determined by a calorimetric procedure described by Vaintraub and Lapteva (1988). Samples (0.5g) were stirred in 10 ml 3.5% HCl. After centrifuging at 10,500 g for 10 min, 0.1 ml of supernatant was taken, made up to 3 ml with distilled water, 1 ml wade solution added, vortexed, centrifuged (4000 g, 5 min) and used for the assay.

Saponin was determined according to Francis *et al.* (2002) with the following minor modifications. Finely ground samples (0.5 g) were stirred in a test tube overnight in 10 ml 80% aqueous methanol. They were then centrifuged (3000 g, 10 min) and supernatant transferred to a 250 ml round bottomed flask. After methanol was evaporated using rotary evaporator the dry material was dissolved in 2.5 ml phosphate buffer solution (PBS) in ultrasonic water bath (35 w, 10 min). After the dissolved material was centrifuged (13,000 g, 5 min) the supernatant was serially diluted in a plate with phosphate buffer solution and 3% RBC. After two hours, the concentrations that hemolysed RBC were recorded. Hemolytic activity is expressed as the inverse of the minimum amount of saponin extract/ml assay medium in the highest dilution that started producing the hemolysis.

Non-protein nitrogen (NPN) was determined according to Makkar (1993a) with minor modifications. In 2 g of the ground sample in a centrifuge tube, 20 ml of 10% trichloroacetic acid (TCA) was added. The content was homogenized with ultra-turrax (20,000 rpm for 4 minutes, 2 x 2 min with intermittent cooling). Then it was centrifuged (5000 g for 10 min) to produce protein free supernatant. Aliquots of this supernatant (8 ml) were analyzed for NPN using Kjeldahl procedure. It was expressed as N/kg DM.

Statistical analysis

The standard error of the mean for the nine observations of each sample of *in vitro* analysis was calculated.

RESULTS

Sisal waste had high ash and lignin, medium level of fiber and phytate and low levels of phenolics, tannins, CP, DOM and ME (Tables 1 – 2). However, it showed hemolytic activity suggesting presence of saponin. Coffee pulp (CPu) and coffee parchment (CPa) had medium level of CP and small amount of phytate. CPu had higher percentage of NPN, DOM, ME, total phenolics, total tannin and VFA but lower NDF, ADF and lignin than CPa. CPa was found to be positive to saponin hemolytic activity test.

Table1. Chemical composition (g/kg DM) and hemolytic activity of saponin of some agro-industrial by-products from Ethiopia.

Feedstuffs	DM	Ash	CP	EE	NDF	ADF	Lignin	NPN	TP	NTP	TT	CT	P	S
Sisal waste	82	177	64	16	333	269	142	2.3	10	8	2	0.1	20	0.8
Coffee parchment	937	42	73	08	744	579	170	2.7	22	5	17	5.0	15	0.4
Coffee pulp	857	29	100	13	368	276	79	64	74	13	60	0.7	14	-
Onion peels	162	90	159	09	194	154	27	12.6	45	12	33	6.9	20	-
Carrot peels	193	108	48	10	162	160	34	3.4	17	8	9	0.5	16	-
Potato peels	247	53	83	02	251	55	16	4.6	8	3	5	0.1	6	1.6
Avocado peels	248	87	71	437	261	233	125	1.2	49	10	39	22.1	9	**
Mango peels	181	42	66	27	237	205	47	1.0	151	21	130	3.8	14	**
Papaya peels	110	138	241	42	203	203	27	12.0	22	9	13	1.1	14	-
Pineapple peels	119	79	82	14	450	208	28	5.0	19	8	11	0.2	15	-
Banana peels	124	163	55	48	308	216	77	1.4	26	9	18	3.0	24	-
Orange peels	233	44	81	10	169	162	06	3.9	51	23	28	0.6	09	-
Cabbage leftover	103	130	137	17	232	183	16	8.1	123	37	86	6.0	14	0.1
Distillery byproduct	150	58	179	77	396	157	48	3.4	20	7	13	0.2	14	-
Brewery byproduct	156	47	187	53	535	336	214	1.5	39	12	26	1.1	18	-
Fishmeal	323	235	490	184	83	39	-	22.5	10	5	5	0.1	6	6.4

*=inverse of the minimum amount of saponin extract per ml assay medium that produced hemolysis. The assay comprised of 1:1 (v/v) of the plant material in PBS and 3% red blood cells.**=Samples that produced agglutination when tested for hemolytic, suggesting presence of lecithin activity; NPN is expressed as g N/kg DM; * analyzed by 72% sulfuric acid; ME and DOM calculated based on gas production standardized to grass.

Table 2. Metabolizable energy (ME, MJ/kg DM), digestible organic matter (DOM, g/kg DM) and concentration of volatile fatty acids (VFA) after incubation in rumen liquor.

Feedstuffs	Acetate	Propionate	Butyrate	Valerie acid	Total VFA*	Acetate: Propionate	ME	DOM
Sisal waste	19.4 ±1.9	4.5±0.4	1.1±0.4	0.1±0.0	25.1±2.5	4.3±0.3	6.6±0.3	568±15
Coffee parchment	7.5±1.1	1.7±0.2	0.7±0.1	0.1±0.0	9.9 ±1.3	4.5±0.4	3.8±0.1	322±4
Coffee pulp	18.9±0.9	5.9±0.4	2.8±0.2	0.3±0.0	27.9 ±1.1	3.2±0.3	8.2±0.1	576±9
Onion peels	25.8±0.2	7.0±0.7	5.3±0.2	0.4±0.1	38.4±0.8	3.7±0.4	10.5±0.3	762±18
Carrot peels	25.1±1.4	7.9±0.4	5.0±0.6	0.4±0.1	38.3 ±1.7	3.2±0.3	10.3±0.4	761±25
Potato peels	22.5±1.6	8.5±3.6	4.1±2.1	0.2±0.1	35.3 ±1.6	3.2±1.9	10.4±0.3	738±19
Avocado peels	8.2±2.2	3.0±0.5	0.9±0.3	0.0±0.0	12.1±2.9	2.7±0.4	13.6±0.3	365±16
Mango peels	26.7±0.4	5.8±0.4	2.9±0.2	0.2±0.0	35.6±0.7	4.6±0.3	10.5±0.5	706±27
Papaya peels	23.7±1.8	7.6±0.3	4.3±0.6	0.5±0.1	36.0±2.2	3.2±0.4	9.9±0.1	716±9
Pineapple peels	27.4±1.4	7.0±0.3	3.9±0.3	0.3±0.1	38.6±1.8	3.9±0.3	10.0±0.2	713±10
Banana peels	20.5±1.3	6.9±0.2	3.0±1.5	0.2±0.1	30.7±2.6	3.0±0.3	9.3±0.2	683±11
Orange peels	30.2±1.7	7.5±0.8	4.8±0.4	0.7±0.1	43.3±2.0	4.1±0.6	11.8±0.4	810±26
Cabbage leftover	25.2±1.2	6.8±0.6	3.7±0.6	1.2±0.1	36.7±1.4	3.8±0.5	10.2±0.2	758±16
Distillery byproduct	16.7±1.1	6.8±0.6	2.5±0.4	0.4±0.1	26.4±0.9	2.5±0.4	9.8±0.4	607±23
Brewery byproduct	12.3±1.5	4.5±0.1	2.0±0.3	0.2±0.1	19.1±1.8	2.7±0.4	7.7±0.4	507±27
Fishmeal	7.6±1.0	2.2±0.4	0.9±0.3	0.7±0.1	11.5±1.7	3.5±0.1	10.6±0.2	630±13

The data are mean ± SD; *iso-C4 and iso-C5, which were present in negligible amounts in most of the feedstuffs, are not considered in the calculation of total VFA and not presented in this Table.

Most of the peels contain less than 100 g/kg DM of ash except for banana, papaya and carrot peels and cabbage leftover. Papaya and onion peels had high CP levels, cabbage leftover medium level of CP and the remaining peels were low in CP. Mango peel had the lowest NPN and onion had the highest amongst kitchen waste and all feeds. Except avocado peel, all the kitchen waste had lower than 50 g/kg DM of EE. Except pineapple peel, all others had lower than 300 g/kg DM of NDF. Most vegetable waste had similar NDF and ADF values indicating kitchen wastes had high ME (9.3–13.6 MJ/kg DM) and DOM (683 to 810 g/kg DM) except avocado peel (365 g/kg DM). They all had very high concentrations of total volatile fatty acids (30.7 to 43.3 mM) except avocado peels (12.1 mM)

Avocado peel had the highest amount of lignin followed by banana and mango peels. Mango peel, followed by cabbage leftover, had the highest amount of phenolics of the kitchen wastes and also of all the feeds and tannins made most of the phenolics. Medium levels of phenolics were found in orange, avocado and onion peels. The wastes had negligible amounts of condensed tannins and small amounts of phytate (8.5 to 23.8 g/kg DM). Only potato peel and cabbage leftover among kitchen waste expressed hemolytic activity of saponin. Mango and avocado peels exhibited agglutination when they were tested for hemolytic activity indicating the presence of lecithin.

Distillery by-product (D-*Atella*) had high NDF, medium level of CP, low NPN, EE, lignin and phytate; moderate level of DOM, ME, VFA concentration, and low level of ash, phenolics and tannin. It was negative to test of hemolytic activity of saponin (Tables 1–2). Brewery by-product (B-*Atella*) had very high NDF, ADF, lignin; medium level of CP, lowest NPN, EE and phytate. It was negative to test of hemolytic activity of saponin, and had much lower DOM and VFA concentration than that of D-*Atella*.

Fishmeal had high levels of ash, CP, EE and ME, medium level of NPN and DOM, minimal amounts of NDF and ADF, secondary plant compounds (except lignin) and VFA production. Fishmeal showed extremely high hemolytic activity of saponin.

DISCUSSION

Distribution, description and annual production of the feedstuffs

According to Edwards *et al.* (1997) sisal (*Agave sisalana*) is widely planted in Ethiopia. It has large, thick, succulent, tough and fibrous leaves. *Agave americana* is grown in drier part of Ethiopia. Fiber comprises only 3% of *Agave sisalana* leaf and the remaining 97% of the leaf is waste. Hawassa Sisal Factory, found in southern Ethiopia, produces about 4,000 tons of leaves annually, which yields 120 tons of fiber and 3,880 tons of waste (personal communication).

Ethiopia produced about 275 metric tons of clean coffee seed in 2006 and the ratio between pulp plus parchment and clean seed is 5:1 (MoARD, 2006). Since there are 5 times the plup plus parchment as there is beans, there are about 1,375 metric tons of coffee by-products produced annually. Earlier, Alemayehu Mengistu (1998) has reported only 30 metric tones of annual pulp and hull production.

In cooperation with the cafeteria of Hawassa University, it was possible to estimate its annual DM kitchen waste production. Known weights of the fresh vegetables were taken before peeling and the amount of peel produced from each vegetable was 20% (cabbage), 25% (onion) and 30% (potato and carrot each). From a total of 936 tons of vegetables consumed (personal communication) about 239 tons of fresh peels and leftovers and 42 tons of DM (239 x 0.1762) were estimated to be produced annually from this University. There are over 21 public universities, large numbers of public and private hospitals, clinics and hotels that have cafeterias that operate in a similar way and produce tremendous amounts of these wastes. The potential of these feed resources (183 MT/annum) has also been visualized from the amount of vegetables consumed domestically during 2006 (12, 7, 176 and 450 mt of cabbage, carrot, onion and potato, respectively) these figures have been obtained when the amount exported is subtracted from total production (MoARD, 2006).

About 228, 211, 71, 55 and 51 metric tones of avocado, banana, papaya, mango and orange fruits were produced in 2006 and most of them were consumed in the country with only small amount of banana, orange, mango and avocado exported (804, 72, 5 and 1 tons in 2006, respectively). The smallest proportions of the peel to whole fresh fruit were from avocado and pineapple (24 and 25%, respectively) and the highest from banana and orange (57% each). The estimated annual productions were about 225 metric tones of the fresh peels and 38 metric tones of DM peels.

A total of 12,291 tons of fish were produced from inland fresh waters of Ethiopia in 2006 (Fisheries Resource Development and Marketing, unpublished report). According to Asrat Tera (2007) 49% of landing is fish offal and 32% of it is DM. Pronce and Gernat (2002) revealed even higher percent of waste (64% of entire tilapia). It could thus be estimated that Ethiopia produces annually about 6,023 tons of fresh fish offal or 1,927 tons of DM offal from its fresh waters. Lake Hawassa, from where the fishmeal was prepared, could produce 44 tons of DM per year and the lakes from southern Ethiopia 788 tons of DM (Asrat Tera, 2007).

Nutritive value of the feedstuffs

Sisal waste is mixed with water to reduce the foam produced in the process of mechanically separating the fiber from the pulp, which takes away some of the water soluble nutrients. Thus saponin, soluble tannin, protein contents and ME could be higher if the waste was not washed with water. However, CP content of the sisal waste was higher than earlier reported (Amanuel Teku, 1982; 76 g/kg DM). Reduced DOM, ME values and concentrations of VFA could be related to the high ash and lignin contents and possibly also to the mixing of sisal waste with water that must have washed away soluble nutrients. Butler and Beyley (1973) reported hemolytic activity of saponin in sisal waste and indicated that it was toxic to livestock when fed in excess. Thus the amount of sisal waste in the diet should be limited.

Because of the high level of NDF, ADF and lignin, the DOM and ME contents of coffee parchment (CPa) were extremely low. CPu had lower levels of NDF, ADF and lignin and thus higher DOM. Even if total phenolics and total tannin contents of CPu were higher than that of CPa, they had less impact on DOM compared to fiber and lignin. Small amount of phytate was present in both. The DOM, ME content and VFA concentrations of CPu were much higher, but the ratio of acetate to propionate lower than those of CPa, although CPu had higher amounts of phenolics than that of CPa. On the other hand the CPa with higher lignin had very low DOM and ME. The effect of high levels of phenolics on DOM was also less pronounced in the feedstuffs with higher amounts of protein (young cactus, cabbage leftover, *Moringa stenopetala*). In these feedstuffs, more than phenolics, lignin reduced DOM.

For dry and wet processed Ethiopian coffee pulp, Getachew Gebru *et al.* (1989) reported that it has high level of NDF (57%, 30%), ADF (52%, 26%), lignin (16%, 6%), soluble phenolics (32.5%, 24.6%) and proantocyanidins (20 A550/g, 11.5 A550/g) respectively, most of the values lie between the values of CPu and CPa in this study. Almeida *et al.* (2005) reported that coffee hull has high concentration of lignin and phenolic compounds in the dry processed pulp, which can form insoluble complexes with proteins and reduce OM and N digestibilities. Although the conclusion is general, it agrees with the results of this study. The work of Getachew Gebru *et al.* (1989) underlined the effect of tannin and caffeine in influencing nutritive value of coffee pulp and suggested chemical treatment and ensiling as possible means of improvement of the nutritive value.

Most processing of vegetables and fruit juices in Ethiopia is currently done manually. The amount and quality of waste produced from peeling of vegetables and fruits depend on individual skills and hand tools used. If vegetables and fruits are not harvested in the field with care, it contributes to losses during peeling. The non-uniformity of size and shape and surface irregularities result in high peel losses during peeling. The proportion of peels of different fruits varied with juice processing techniques and varieties of fruits. It was found out that 225 metric tones of fresh peels and 38 metric tones of DM peels were annually produced, and if the smallest amount of the estimated annual waste produced is recovered as livestock feed, it will definitely be part of the solution to the feed deficit.

An average loss of 28% of potato tuber during peeling was reported (Burton, 1989), which is significantly lower than the proportions of the peel obtained in this study. Mango peels and cabbage leftover have high tannin content and could be used as additives in silage preparation (Tabacco *et al.*, 2006). From a feeding experiment of dehydrated kitchen waste for laying hens, it was concluded that it is safe and nutritious and its inclusion up to 25% in the diet did not have any negative influence (Sadao, 2005). The kitchen wastes could be ensiled with hay. They could be fed directly to animals as a portion of the diet.

The Ethiopian traditional brewery (BB) and distillery by-product (DB) called *Atella* is produced in appreciable quantities all over the country throughout the year. *Atella* is comprised of protein, fat, insoluble carbohydrates, vitamins, minerals and yeast formed during fermentation. Moreover, its nutritional value is influenced by the raw materials used and the different processes performed (Ali Beker, 1985). Excessive heat applied in the traditional distillation process could possibly result in nutritionally unavailable protein-carbohydrate complex in DB. Digestible organic matter and VFA concentration of BB were much lower than that of DB possibly due to higher fiber and lignin contents of BB. The stem and leaf of Gesho (*Rhamus prenoids*) added as facilitator of fermentation increased fiber and lignin contents of BB. Lower DOM of *Atella* agrees with earlier report (Solomon Demeke, 2007). Although *Atella* has reasonable amount of CP and could be considered as protein supplement to monogastric animals its high fiber content limits digestibility and intake. Solomon Demeke (2007) reported that fiber of *Atella* is indigestible by poultry and has lower intake value, protein efficiency ratio and weight gain than commercial brewers' grains. These products could also be ensiled and fed during the dry season.

Low DOM of fishmeal could be associated with high amount of saponin and EE because it was reported that acacia saponins decreased gas production and increased microbial mass/unit of substrate DM (Makkar *et al.*, 1998). However, Alexander *et al.* (2007) reported that saponin in *M. oleifera* did not influence partitioning of fermentation end-products. Maaza Sahle and Beyene Chichaybelu (1982) evaluated nutritive value of fishmeal to layers in Ethiopia and obtained unsatisfactory results due to poor processing of fishmeal. The fiber and lignin in fishmeal must have come from gut content. However, it can serve as sources of protein and energy. Saponin in fishmeal could have come from phytoplankton of the gut contents. The availability of major nutrients, well balanced amino acid profile and omega-3 and 6 fatty acids in fishmeal increase its feeding value to simple stomached animals (Donald and William, 2002). The use of fishmeal increases the level of long chain omega-3 fatty acids in livestock meat and has beneficial health effects for humans consuming such products (Lopez *et. al.*, 1999).

CONCLUSION

Most of the feedstuffs studied had similar or even higher metabolizable energy and DOM than that of the standard hay and if judiciously mixed among each other and with other feeds they are good sources of protein (FM, PaP, BB, DB), energy (AP, OrP, FM, OnP, MP, PoP, CP, CL) and water (SW) and are worthy of feeding to livestock. Most of the feedstuffs are succulent which could limit their DM contribution. However, some like kitchen waste have to be at least dried before feeding to livestock, which would improve their DM value. Sisal waste could serve as water sources to livestock especially during dry seasons or drought as they can be fed fresh.

The feedstuffs could be supplements to low-quality forages. This would be of special interest for Ethiopia with large number of ruminants that are fed on crop residues. Using them as livestock feed reduces environmental pollution, motivates small-scale feed processing units, and provides alternative and beneficial ways of disposing waste, in addition to enhancing and sustaining animal production and improving feed self-sufficiency. However, further research is needed to determine the appropriate method of offering the feedstuffs, optimum level of incorporation in diets, etc.

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