ORIGINAL ARTICLE

Availability, utilization as feed and chemical composition of vegetable by-products in urban and peri-urban areas of West Arsi zone and Sidama regional state

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ABSTRACT

This study was undertaken to assess the availability, utilization, as feed, and chemical composition of vegetable by-products in selected urban and peri-urban areas of West Arsi zone and Sidama Regional State. A Multi-stage purposive sampling technique was used to select study areas and a total of 306 respondents (102 each from Shashemene, Hawassa and Yirgalem) were randomly selected and interviewed. Samples of the most prevalent and commonly utilized five vegetable by-products (VBPs) were analyzed for chemical composition and subjected to in vitro dry matter digestibility (IVDMD). The data collected were analyzed using two way analysis of variance and Chi-square for quantitative and qualitative parameters, respectively. The results indicate that potato, cabbage, sweet potato, tomato and carrot by-products were the most dominant VBPs available and utilized as livestock feed in the study area. Vegetable by-products were fed to cattle, small ruminants and chicken solely after being processed. However, perishability, safety issues, lack of storage facilities and conservation awareness were the major limitations of VBPs utilization, as feed. On the contrary, low market price, high demand and feed quality, palatability and reduction of environmental pollution were the main opportunities for VBPs utilization, as feed. The crude protein content of VBPs was within the range of 4.49-18.29%. The mean neutral detergent fiber content of the VBPs collected from different locations was less than 45%. The acid detergent fiber and acid detergent lignin contents were within the range of 10.08-35.08 and 1.23-9.76%, respectively. The IVDMD of VBPs was within the range of 78.73-89.45%, regardless of location. In conclusion, vegetable by-products are widely available and utilized as an alternative feed resource within urban and peri-urban farming communities of the study area. Feeding experiments which evaluate the performance of animals fed with these vegetable by-products are recommended.

Key words: Potato residue, Constraints and opportunities, Production system, Perishability

INTRODUCTION

The urban and peri-urban livestock production constitutes an important sub-sector of the agricultural production system in Ethiopia. Under smallholder farming around urban and peri-urban areas the use of agro-industrial and vegetable by-products are common. Vegetable by-products are available at household level, hotels and cafes. Smallholder farmers especially who are involved in rearing small ruminants and dairy cows use these by-products. It is important to document these by-products utilization in terms of species, types and amount at household and industrial level. By using, such by-products feed cost and feed shortage could significantly be reduced (Mahgoub *et al.*, 2018; Matthew *et al.*, 2018).

In recent years, the interest in using by-products of agro-industrial by-products has increased significantly, attributed to the volume of production and composition of the by-products as a source of bioactive compounds (Dilucia *et al.*, 2020) and the expansion of vegetable and fruit processing industries in Ethiopia. The use of vegetable processing by-products as animal feed has economic, environmental and social implication (Kasapidou, *et al.*, 2015; Malenica and Bhat, 2020). According to Kumar *et al.* (2020) large amount of peel waste generated from vegetable-based industries and household kitchens create serous disposal and environmental problems.

Processing of vegetable alone generates significant by-products, accounting to 25–30% of the total products (Kumar et al., 2020). Despite the vegetable by-products production at household and country levels, the availability, constraints and mode of utilization of such by-products as livestock feed is not well documented in Ethiopia. Nevertheless, the utilization of vegetable by-products as animal feed is one of the most important option to alleviate the economic loss and environmental problems, resulting from the accumulation of the by-products. Therefore, assessing the utilization of vegetable by-products, evaluation of chemical composition and determination of *in vitro* dry matter digestibility under the Ethiopian condition are important. Thus, this study assessed the availability, utilization, nutritional composition of vegetable by-products in selected urban and peri-urban areas of West Arsi zone and Sidama Regional State.

MATERIALS AND METHODS

Description of study areas

Hawassa city is located 275 km South West of Addis Ababa and located between 6°83′ to 7°17′ N and 38°24′ to 387°72′ E, at an altitude of 1750 m above sea level. It receives mean annual rainfall of 955 mm and has an average annual temperature of 20°C (Haben *et al.*,2020). Yirgalem town is situated in the Dale district of Sidama Regional State 42 km east of Hawassa city. The majority of the populations in Dale are subsistence farmers. The economic activity of the district is mainly agriculture with rearing farm animals and cultivating land. The major crops are coffee, enset, maize, haricot bean, chat, sugar cane, banana and avocado (CSA, 2016). Shashemene town is situated at a distance of 250 km south of Addis Ababa and 25 km North of Hawassa. Geographically Shashemene is located between 7°12' North and 38° 36' East, at an altitude range of 1700-2600 meters above sea level. The town is characterized by bi-modal rainfall of long and short rainy seasons. The average minimum and maximum annual temperature ranges between 9°C and 24°C, respectively and the mean relative humidity is about 75% (CSA, 2013).

Sampling technique, sample size and data collection

This study involved household survey, chemical analysis and *in-vitro* dry matter digestibility determination. Shashemene from West Arsi and Hawassa and Yirgalem from Sidama Regional State were purposely selected based on the availability of the vegetable by-products. Primary data were collected with the use of questioner and secondary data were collected through discussions with district Livestock and Fishery Development Offices and Urban Agriculture Offices of the respective study area. Moreover, the necessary information were obtained from key informants (*kebele* and sub-city leaders, developmen agents, animal health experts) of each specific study area to identify and select the specific sub-city and *kebele* (lower level administration under Ethiopian context) , with high potential in vegetable by-product production and utilization. Three sub-cities from urban and three *kebeles* from peri-urban of each study area were purposely selected based on the potential production and utilization, as feed of vegetable by-products. The households of each sub-city and *kebele* were stratified in to vegetable by-products utilizers and non-utilizers. The respondents were selected randomly (Table 1). Sample size were determined according to the formula given by Yamane (1967). A total of 306 households were interviewed to assess the availability and utilization, as feed, of vegetable by-products. The survey was conducted using semi-structured questionnaire managed by experienced and trained enumerators. The data collected include type of available vegetable by-product, method of utilization, as feed, parts used in feeding, preferred livestock species, seasonal availability, processing methods, effect on animals, method of storage, storage problems, constraints and opportunities of utilization. Finally adequate sample were taken from the five most widely available and utilized vegetable by-products (potato peel, cabbage leaf, culled sweet potato, tomato and carrot) for chemical analysis and *in- vitro* dry matter digestibility determination.

Sample collection and preparation

Samples of potato peels and cabbage leaf were collected from hotels, restaurants and cafés immediately after processing, while culled sweet potato, tomato and carrot were collected from retailers of open markets. The samples were pooled by type and chopped using scissors and knives, and air-dried. These were further dried at 60°C for 48h in forced draft oven and grinded in Wiley mill to pass through 1 mm sieve. The prepared samples were stored in airtight plastic bags until required for chemical analysis and *in- vitro* dry matter digestibility determination.

Table 1. Sample size from each sub-city or *kebele* of the study areas

Study areas		Sub-city *or Kebele*	Population size	Sampled Proportion (%)	Sample size	Total
Shashemene	Peri urban	Maja Damma	55	23.6	13	40
		Ilala Korke	63	23.1	15	
		Alelu Ilu	51	23.5	12	
	Urban	Bulchana	106	23.6	25	62
		Alelu	85	23.5	20	
		Burka Guddina	72	23.6	17	
Hawassa	Peri-urban	Tula 01	58	24.1	14	43
		Dato Odahe	66	24.2	16	
		Chefe Kotijabesa	55	23.6	13	
	Urban	Tabor	95	23.2	22	59
		Menehariya	71	23.9	17	
		Addis Ketema	87	22.9	20	
Yirgalem	Peri-urban	Masincho	75	24	18	45
		Awada	53	22.6	12	
		Tula	63	23.8	15	
	Urban	Abosto	98	23.5	23	57
		Awada Stadium	76	23.7	18	
		Kidest Mariam	68	23.5	16	
Total		18	1296	423.9	306	306

Chemical analysis and *in vitro* dry matter digestibility

Dry matter, total ash, ether extract and nitrogen (N) were analyzed according to the procedures of AOAC (1990). Crude protein was calculated as N *6.25. Neutral detergent fiber (NDF) was analyzed according to the procedures of Van Soest *et al*. (1991) whereas acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed according to the procedures of Van Soest and Robertson (1985).

In vitro dry matter digestibility was determined by the method of Tilley and Terry (1963) as modified by Van Soest and Robertson (1985) using DAISY incubator in which the second stage (pepsin digestion) was substituted with neutral detergent solution. Rumen fluid was obtained by means of esophageal tube from the rumen of three sheep kept on a maintenance diet. They were fed native pasture hay ad libtum supplemented with 300 g homemade concentrate mix, which was made by mixing wheat bran and noug seed cake at the proportion of 70:30. Rumen fluid was collected before morning feeding and immediately taken to the laboratory using a thermos flask. It was filtered through two layers of cheesecloth and flushed with CO_2. Sample of 0.25 g weighed in to ANKOM Filter bag (ANKOM^R Technology, # F57) were added to ANKOM jars containing rumen fluid and medium mixture (solution A: KH_2PO_4, $MgSO_4{\bullet}7H_2O$, NaCl, $CaCl_2{\bullet}2H_2O$, urea, reagent grade and B: Na_2CO_3 and $Na2S{\bullet}9H_2O$) of 1:4 ratio and incubated in an incubator at 39°C for 48 h. After incubation for 48 h, the filter bags were washed with tap water until it was clear; soaked with acetone and then further extracted with neutral detergent solution in the ANKOM^{220} fiber analyzer.

Data analysis

All collected data were analyzed using SPSS (2016) version 20 statistical software. The analyzed data were presented using tables, figures, frequencies, percentages, means and standard error. The means of quantitative data were compared by employing two-way analysis of variance using General Linear Model (GLM) procedures. The means were separated using Tukey test and significant level was considered at P<0.05. The statistical differences between qualitative variables that were analyzed following cross tabulation (Chi-square tests procedure) and was also declared significant at P<0.05.

The statistical model used for data analysis was:

$$Y_{ijk}=\mu+L_i + S_j + (L*S)_{ij} + e_{ijk}$$

Where Y_{ijk} = the dependent variable; μ = over all mean; L_i = the effect of location; S_j = the effects vegetable species; $(L*S)_{ij}$ = interaction effects of location and vegetable species and e_{ijk} = the error term.

For parameters required ranking, the indices were calculated using the principle of weighted average, using the formula adopted by Musa *et al*. (2006).

Index = Rn*C1+Rn-1*C2+….R1*Cn/∑ Rn*C1+ Rn-1*C2+…. + R1

Rn = Value given for the least ranked level (for example if the least rank is 7th rank, then; Rn=7, Rn-1=6 and … R1= 1)

Cn = Counts of the least ranked level (in the above example, the count of the 7th rank = Cn and the counts of the 1st rank = C1)

RESULTS AND DISCUSSION

Availability and utilization of vegetable by-products in the study areas

Availability of vegetable by-products

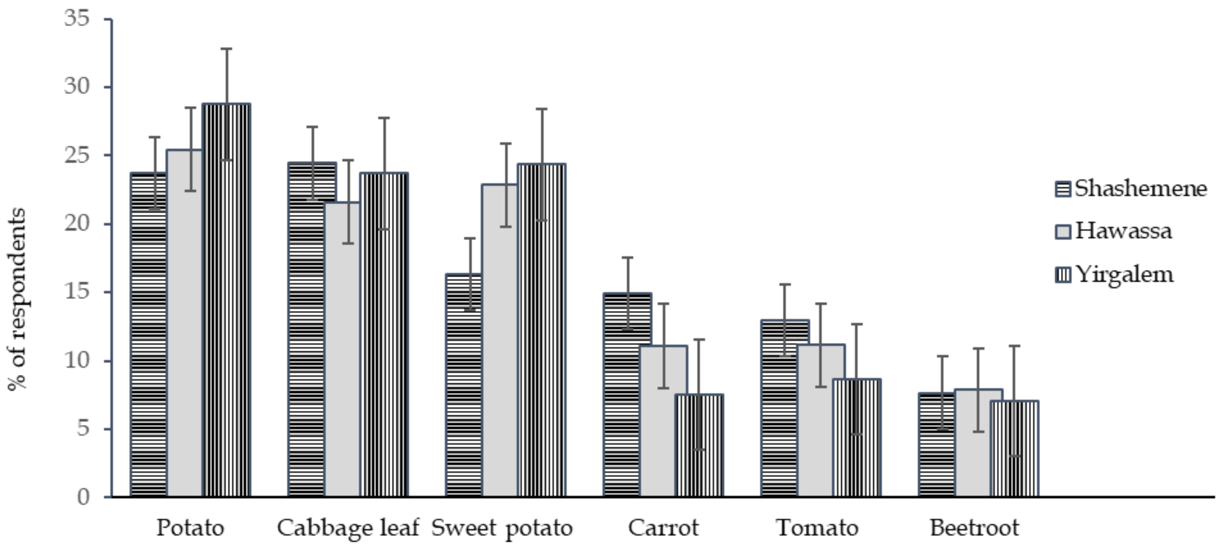
The major vegetable by-products widely available in the study areas are given in Figure 1 A and B. Potato, cabbage, sweet potato, carrot, tomato and beetroot by-products were the major vegetable by-products available in urban livestock production system. Potato, cabbage, tomato, sweet potato, carrot, and beetroot by-products were the major available vegetable by-products in peri-urban production system in descending order.

The majority (77%) of the vegetable by-products utilizers in urban Shashemene indicated that potato, cabbage and tomato by-products were the most commonly available vegetable by-products followed by t sweet potato and carrot by-products in descending order. The majority (97.5%) of the respondents in peri-urban Shashemene indicated that potato, cabbage, sweet potato, tomato and carrot by-products were the most prevalent vegetable by-products. The majority of vegetable by-products utilizers in urban and peri-urban areas of Hawassa and Yirgalem indicated that potato, cabbage, sweet potato, tomato and carrot by-products are widely available vegetable by-products. The results obtained also indicated that potato peels, cabbage leaf and other rejected vegetables, collected from hotels, restaurants, cafés, and individual households have great potential for livestock feeding.

According to FAO (2018) substantial amounts of vegetable by-products accumulated at production, marketing and consumption sites are used as animal feed in urban and peri-urban dairy cattle farming. Similarly, Ezeldin *et al.* (2016) showed that vegetable by-products are useful ruminant feed resource. There is an increase in the number of vegetable by-products producers and suppliers in urban and peri-urban areas indicating the future potential of these by-product availability and utilization. Potato by-products (peels and culled potato) were the most commonly available and widely used vegetable by-products, as feed, resource in the current study, the results of which is in line with that of Ncobela *et al.* (2017) who reported that potato by-products are widely available alternative feed with high nutritional value. According to Devrani *et al.* (2018), potato peel, culled potatoes and other vegetable by products including fermented potato by-products obtained from processing installations are utilized as animal feed and nitrogen source in ruminant feeding.

The results of the current study indicated that cabbage, tomato and carrot by-products were the most widely available vegetable by-products used, as feed, in the study areas, which are consistent with that of Wadhwa and Bakshi (2013) who reported that vegetable by-products such as cabbage leaves, tomato pomace and carrot are rich source of nutrients when fed either after drying or ensiling.

A)



B)

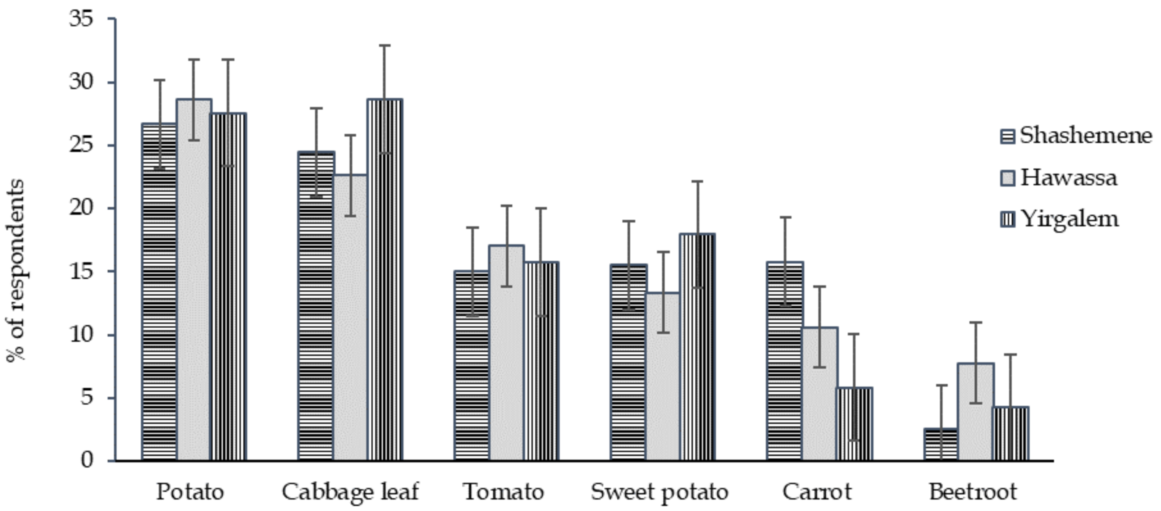


Figure 1: Percent of respondents (mean ± SE) reported the major vegetable by-products (mean ± SE) available in urban (A) and peri-urban (B) production systems of the study areas

Seasonal availability of vegetable by-products in the study areas

The seasonal availability of vegetable by-products in the study areas are presented in Table 2 and 3. The current results showed that the availability of vegetable by-products varied between seasons. The majority of the respondents in the urban production system indicated that the most utilized vegetable by-products in the study areas are available throughout the year with the exception of sweet potato and beetroot by-products. Sweet potato by-products were relatively abundant during December - February. Moreover, the results of the current study showed that potato by-products and cabbage leaf are relatively abundant from December to March and June to August in the urban production system. Carrot and tomato by-products are scarce throughout the year.

In the peri-urban production system, t90.8% of the respondents indicated that most of the vegetable by-products utilized, as feed, are quantitatively important from November to May with the exception of potato by-products and cabbage leaf, both of which are available throughout the year. However, the extent of availability varies with months and types of vegetable by-products. Potato by-products and cabbage leaf are abundant from December to March and June to August in the peri-urban production system. Sweet potato by-products are abundant from December to February in peri-urban production system. The availability of carrot, tomato and beetroot by-products were limited to November to May and not available during the remaining months in peri-urban production system.

The majority of vegetable by-product utilizers, as feed, in both urban and peri-urban production systems of the study areas revealed that they used these by-products more frequently during feed shortages, especially from December to May. In line with this finding Fiseha (2018) reported that non-conventional feed resources are available throughout the year and primarily utilized during the dry season (December to May). Davis *et al.* (2015) and Das *et al.*(2019) also indicated that vegetable by-products are available year round. Similarly, Thomas *et al.* (2020) reported that vegetable by-products are available throughout the year, including times of feed scarcity.

Table 2. Seasonal availability of the major vegetable by-products in urban production system of the study areas

Location	Vegetable by-products	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Shashemene	Potato	*	*	*	**	**	**	**	*	*	**	**	**
	Cabbage	*	*	*	**	**	**	**	*	*	**	**	**
	Sweet potato	-	-	-	**	**	**	-	-	*	*	*	*
	Carrot	*	*	*	*	*	*	*	*	*	*	*	*
	Tomato	*	*	*	*	*	*	*	*	*	*	*	*
	Beetroot	-	-	*	*	*	*	*	*	*	*	-	-
Hawassa	Potato	*	*	*	**	**	**	**	*	*	**	**	**
	Cabbage	*	*	*	**	**	**	**	*	*	**	**	**
	Sweet potato	-	-	-	**	**	**	*	*	*	*	*	*
	Carrot	*	*	*	*	*	*	*	*	*	*	*	*
	Tomato	*	*	*	*	*	*	*	*	*	*	*	*
	Beetroot	*	*	*	*	*	*	*	*	*	*	*	*
Yirgalem	Potato	*	*	*	**	**	**	**	*	*	**	**	**
	Cabbage	*	*	*	**	**	**	**	*	*	**	**	**
	Sweet potato	-	-	-	**	**	**	*	*	*	*	*	*
	Carrot	*	*	*	*	*	*	*	*	*	*	*	*
	Tomato	*	*	*	*	*	*	*	*	*	*	*	*
	Beetroot	-	-	*	*	*	*	*	*	*	*	-	-

**= abundant in availability, *= limited in availability, - = not available

Methods and problems of vegetable by-products utilization in the study areas

The methods of vegetable by-products utilization, as feed, are presented in Table 4. The majority of the respondents in urban and peri-urban livestock production systems feed vegetable by-products to livestock without mixing with other feeds. Only few respondents in urban and peri-urban livestock production systems feed vegetable by-products mixed with salt. Almost all respondents in urban and peri-urban study areas feed vegetable by-products for livestock in wilted forms. This indicated the higher moisture content and perishability of these by-products governs methods of its utilization. The methods of vegetable by-product utilization varied among locations. The majority of the respondents in urban and peri-urban livestock production systems processed vegetable by-products before feeding. Chopping and wilting were commonly practiced by urban livestock keepers followed by wilting. In peri-urban livestock production system only wilting was the most commonly used practice reported followed by chopping and wilting.

Vegetable by-products processing practices varied among locations. The majority of the respondents in Shashemene and Yirgalem process vegetable by-products before feeding, whereas the majority of the respondents in Hawassa feed without processing. According to the present finding, most of the respondents in Shashemene chop and wilt vegetable by-products before feeding, whereas the majority of the respondents in Yirgalem wilt for a few hours before feeding. .

Wadhwa and Bakshi (2013) reported that vegetable by-products (potato, cabbage, tomato and carrot by-products) are fed whole or chopped and used either in fresh, dried or ensiled form. The practice of wilting vegetable by-products before feeding is consistent with the finding of Bhila *et al.* (2010) who indicated that sun drying of cabbage and beetroot by-products reduced microbial load and might be an acceptable method for use by small scale farmers.

Mahgoub *et al.* (2018) also reported that vegetable by-products could be used as animal feed after drying. Tegene *et al.* (2009) suggested that sun-drying of kitchen wastes before feeding to livestock is advisable to optimize the dry matter intake. This showed that processing of vegetable by-products is required to reduce the risk on animal health that may arise when using vegetable by-products without processing aimed at increasing intake and animal performance.

The majority of respondents in urban and peri-urban livestock production systems indicated that it is difficult to store vegetable by-products due to its perishable nature and lack of appropriate storage facility, the result of which is consistent with that of Thomas *et al.* (2020) who reported that high moisture content of most vegetable by-products makes them perishable and difficult to handle, transport and store. The majority (98.1%) of the vegetable by-products utilizers in the study areas have not observed any negative side effects of utilization of vegetable by-products on livestock health (Figure 2). Storage of vegetable by-products is less common in the study areas. Farmers have also reported that they do not feed spoiled vegetable by-products. Few respondents in urban Hawassa and Yirgalem, as well as peri-urban Shashemene and Hawassa indicated that utilization of vegetable by-products results in bloating if not dried before feeding in excess. Das *et al.* (2019) indicated that processed vegetable by-products had similar impacts with that of conventional concentrate on daily gain, dietary intake, digestibility and health status of bulls. This indicates the benefits of using vegetable by-products which could reduce competition for cereal grain and in reducing pollution to the environment. Wadhwa and Bakshi (2013) reported that processed vegetable by-products can be fed to animals without affecting their palatability, nutrient consumption and health or performance.

Table 3. Seasonal availability of the major vegetable by-products in peri-urban setting of the study areas

Location	Vegetable by-products	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Shashemene	Potato	*	*	**	**	**	**	**	*	*	**	**	**
	Cabbage	*	*	*	**	**	**	**	*	*	**	**	**
	Sweet potato	-	-	-	**	**	**	-	-	*	*	*	*
	Carrot	-	-	*	*	*	*	*	*	*	-	-	-
	Tomato	-	-	*	*	*	*	*	*	*	-	-	-
	Beetroot	-	-	*	*	*	*	*	*	*	-	-	-
Hawassa	Potato	*	*	**	**	**	**	**	*	*	**	**	**
	Cabbage	*	*	*	**	**	**	**	*	*	**	**	**
	Sweet potato	-	-	-	**	**	**	*	*	*	*	*	*
	Carrot	-	-	*	*	*	*	*	*	*	-	-	-
	Tomato	-	-	*	*	*	*	*	*	*	-	-	-
	Beetroot	-	-	*	*	*	*	*	*	*	-	-	-
Yirgalem	Potato	*	*	*	**	**	**	**	*	*	**	**	**
	Cabbage	*	*	*	**	**	**	**	*	*	**	**	**
	Sweet potato	-	-	*	**	**	**	*	*	*	*	*	*
	Carrot	-	-	*	*	*	*	*	*	*	-	-	-
	Tomato	-	-	*	*	*	*	*	*	*	-	-	-
	Beetroot	-	-	*	*	*	*	*	*	*	-	-	-

**= abundant in availability, *= limited in availability, - = not available

Table 4. Methods of vegetable by-products utilization in urban and peri-urban production systems of the study areas

Variable		Mode of utilization (Freq. (%))			P-value
	Location	Mixed with concentrate	Alone	Mixed with salt	
Production system	Urban (N=178)	7 (3.93)	139 (78.09)	32 (17.98)	0.018
	Peri-urban (N=128)	4 (3.12)	109 (85.16)	15 (11.72)	
Location	Shashemene (N=102)	7 (6.86)	79 (77.45)	16 (15.69)	0.000
	Hawassa (N=102)	4 (3.92)	71 (69..61)	27 (26.47)	
	Yirgalem (N=102)	-	100 (98.04)	2 (1.96)	
		Processing techniques (Freq. (%))			
	Location	Chopping and wilting	Wilting	Not processed	
Production system	Urban (N=178)	66 (37.08)	50 (28.09)	62 (34.83)	0.029
	Peri-urban (N=128)	31 (24.22)	45 (35.16)	52 (40.62)	
Location	Shashemene (N=102)	52 (50.98)	6 (5.88)	44 (43.14)	0.000
	Hawassa (N=102)	29 (28.44)	11 (10.78)	62 (60.78)	
	Yirgalem (N=102)	16 (15.69)	81 (79.41)	5 (4.9)	
		Storage condition (Freq. (%))			
	Location	Stored	Not stored		
Production system	Urban (N=178)	10 (5.62)	168 (94.38)		0.955
	Peri-urban (N=128)	8 (6.25)	120 (93.75)		
Location	Shashemene (N=102)	15 (14.71)	87 (85.29)		0.000
	Hawassa (N=102)	3 (2.94)	99 (97.06)		
	Yirgalem (N=102)	-	102 (100)		

Freq. = frequency, N= number of respondent %= percentage

The majority (98.1%) of the vegetable by-products utilizers in the study areas have not observed any negative side effects of utilization of vegetable by-products on livestock health (Figure 2). Storage of vegetable by-products is less common in the study areas. Farmers have also reported that they do not feed spoiled vegetable by-products. Few respondents in urban Hawassa and Yirgalem, as well as peri-urban Shashemene and Hawassa indicated that utilization of vegetable by-products results in bloating if not dried before feeding in excess. Das *et al.* (2019) indicated that processed vegetable by-products had similar impacts with that of conventional concentrate on daily gain, dietary intake, digestibility and health status of bulls. This indicates the benefits of using vegetable by-products which could reduce competition for cereal grain and in reducing pollution to the environment. Wadhwa and Bakshi (2013) reported that processed vegetable by-products can be fed to animals without affecting their palatability, nutrient consumption and health or performance.

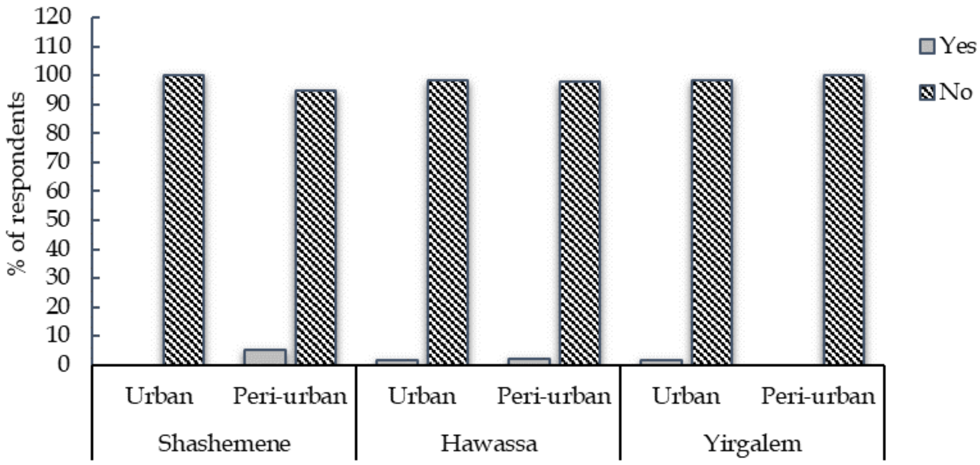


Figure 2: Mean percent of respondents reporting problems of feeding vegetable by-products on livestock health in the study areas

Major constraints of vegetable by-products utilization in the study areas

The constraints of vegetable by-products utilization in the study areas are presented in Table 5. The results obtained indicated that perishability, poor quality, lack of storage facility, lack of awareness and bulkiness are the major problems of vegetable by-products utilization, as feed, in urban and peri-urban livestock production systems. Perishability, safety and lack of storage facility were the three key top constraints of vegetable by-products utilization ranked by respondents in urban and peri-urban Shashemene, Hawassa and Yirgalem.

Perishability of the vegetable by-products was the first constraints limiting its utilization the results of which was consistent with Nora *et al.* (2017) who reported that vegetable by-products are highly perishable as compared with other biological by-products. According to the results of the current study, safety and lack of appropriate storage facilities were the most common problems of vegetable by-products utilization, as feed, followed by lack of awareness in urban and peri-urban areas. Moreover, Wadhwa *et al.* (2015) and Bakshi *et al.* (2016) reported that contaminants mainly pesticides, mycotoxins, heavy metals and other particles are the major issues in vegetable by-products utilization as livestock feed. The results of the present study also indicated that lack of storage facility, lack of awareness, and bulkiness were the most common issues in vegetable by-products utilization as feed. Thomas *et al.* (2020) reported that the moisture content of most vegetable by-products were above 80 %, which makes them perishable and difficult to handle, transport and store.

Table 5. The major constraints of vegetable by-products utilization in the study areas

Production system	Constraints	Location							
		Shashemene		Hawassa		Yirgalem		Overall	
		Index	Rank	Index	Rank	Index	Rank	Index	Rank
Urban	Perishability	0.262	1	0.257	1	0.270	1	0.263	1
	Safety	0.211	2	0.220	2	0.194	2	0.208	2
	Lack of storage	0.195	3	0.194	3	0.196	3	0.195	3
	Inadequate supply	0.096	6	0.095	6	0.085	6	0.092	6
	Lack of awareness	0.129	4	0.121	4	0.132	4	0.127	4
	Bulkiness	0.107	5	0.113	5	0.123	5	0.115	5
Peri-urban	Perishability	0.260	1	0.259	1	0.259	1	0.259	1
	Safety	0.228	2	0.233	2	0.194	2	0.218	2
	Lack of storage	0.174	3	0.185	3	0.192	3	0.183	3
	In adequate supply	0.112	5	0.080	6	0.082	6	0.091	6
	Lack of awareness	0.121	4	0.120	5	0.131	5	0.124	4
	Bulkiness	0.106	6	0.124	4	0.142	4	0.124	4

Major opportunities of vegetable by-products utilization in the study areas

The major opportunities of vegetable by-products utilization in study areas are presented in Table 6. The result obtained indicated that low price, relatively good feed quality, high demand for vegetable by-products utilization, source of income, high palatability and reduction in environmental pollution were the major opportunities of vegetable by-products utilization, as feed, identified by respondents in urban and peri-urban production systems. The majority of vegetable by-products utilizers in the urban and peri-urban study areas ranked low price , good feed quality and high demand as first, second and third major opportunities of vegetable by-products utilization, as feed. This finding is in line with that of Ezeldin *et al.* (2016) and Mahgoub *et al.* (2018) who reported that effective and efficient utilization of vegetable by-products would reduce the cost of animal feeding, increase farmers' profits, generate an array of value-added products and help in waste management and reduction of environmental pollution. In addition, Sahoo *et al.* (2021) reported that vegetable by-products are potential feedstuff for ruminants and it is efficient to minimize environmental impacts associated with disposal of wastes. Moreover, San Martin *et al.* (2016) indicated that vegetable by-products are found to be nutritionally appropriate for use in animal feeding.

Table 6. The major opportunities of vegetable by-products utilization, as feed, in the study areas

Production system	Opportunities	Location							
		Shashemene		Hawassa		Yirgalem		Overall	
		Index	Rank	Index	Rank	Index	Rank	Index	Rank
Urban	Low price	0.257	1	0.262	1	0.270	1	0.263	1
	Good source of livestock feed	0.220	2	0.235	2	0.199	2	0.218	2
	Reduce environmental pollution	0.077	6	0.082	6	0.128	6	0.096	6
	High demand for vegetable by-products	0.183	3	0.185	3	0.135	4	0.168	3
	Highly palatable	0.153	5	0.120	4	0.139	3	0.137	4
	Source of income	0.110	4	0.116	5	0.130	5	0.119	5
Peri-urban	Low price	0.264	1	0.268	1	0.250	1	0.261	1
	Good source of livestock feed	0.239	2	0.221	2	0.202	2	0.221	2
	Reduce environmental pollution	0.084	6	0.092	6	0.167	4	0.114	6
	High demand for vegetable by-products	0.148	3	0.178	3	0.175	3	0.167	3
	Highly palatable	0.124	5	0.114	5	0.111	5	0.116	4
	Source of income	0.142	4	0.126	4	0.095	6	0.121	5

Nutritional composition and *in vitro* dry matter digestibility of commonly utilized vegetable by-products

The chemical composition and *in vitro* dry matter digestibility of the vegetable by-products are presented in Table 7. The interaction effect of location and type of vegetable by-product showed highly significant difference (p<0.01) in chemical composition except for ADL (p<0.05) and *in vitro* dry matter digestibility. Cabbage leaf had higher (p<0.01) total ash content than the others followed by culled tomato in all locations. As compared with other vegetable by-products, cabbage leaf had higher (p<0.05) CP content followed by culled tomato while culled sweet potato tuber had lower CP (p<0.05) than the others in all locations. Culled tomato had the highest (p<0.01) NDF content while culled sweet potato tuber had the lowest NDF (p<0.01) in all locations. Culled tomato had the highest (p<0.01) ADF content in all locations while potato peel and culled sweet potato tuber had the lowest (p<0.01) ADF content. Culled tomato from all location and culled carrot from Shashemene had higher (p<0.01) ADL content while culled sweet potato tuber, potato peels and cabbage leaf had the lowest (p<0.01) in all locations. Culled tomato had the highest (p<0.01) EE content while potato peel and culled sweet potato tuber had the lowest (p<0.01) in all locations. Cabbage leaf from all locations and culled sweet potato tuber and potato peel from Yirgalem had the highest (p<0.01) IVDMD while culled tomato from all locations and culled carrot from Yirgalem had the lowest IVDMD (p<0.01).

The mean total ash content of cabbage leaf in the present finding was the highest as compared with other vegetable by-products, the value of which was lower than the value (16.8%) reported by Nkosi *et al.* (2016) but higher than 12.1% reported by Mustafa and Baurhoo (2018). The mean total ash content of culled sweet potato tuber was significantly lower than that of the others, which is higher than the values (4.7, 4.5, 4.7 and 4.8%) that reported by Gebreegziabher *et al.* (2014) for the roots of Belela, Temesgen, Beletech and Tulla sweet potato varieties, respectively.

The mean CP content of cabbage leaf was the highest as compared with other vegetable by-products, which is consistent with the value (18.4%) reported by Nkosi *et al.* (2016) for discarded cabbage but higher than the value (14 %) reported by Mustafa and Baurhoo (2018) and lower than the CP value of other root crop leaves reported by Aberra *et al.* (2018). The mean CP contents of sweet potato tuber was the lowest and is in line with the value (4.81%) reported by Murugan *et al.* (2012), but lower than the results (6.9, 7.7, 6.8, and 6.3 %) reported by Gebreegziabher *et al.* (2014) for the roots of Belela, Temesgen, Beletech and Tulla sweet potato varieties, respectively.

According to the results of the current study, the mean NDF, ADF and ADL contents of culled tomato was the highest t which was much lower than the result (48.9, 42.9 and 10.2%) reported by Kefyalew *et al.* (2015) for tomato pomace, respectively. The NDF and ADF content in the current experiment was lower than the value (50.3 and 36.9%) reported by Das *et al.* (2019) for NDF and ADF of tomato waste, respectively. However, the mean of NDF, ADF and ADL contents of culled tomato in current finding was higher than the values (26, 21.7 and 19.5%) reported for rejected tomato fruit by Ventura *et al.* (2009), respectively. The mean NDF content of sweet potato tuber was the lowest but higher than the value reported by Gebreegziabher *et al.* (2014). The variation in chemical composition might be due to varietal differences in vegetable by-products and environmental factors which is consistent with the report of Lee (2018) who indicated that the nutritive value of forage crops varies due to species and agro ecological differences.

Compared with other vegetable by-products, cabbage leaf had the highest *in-vitro* dry matter digestibility which is higher than the value reported by Wadhwa *et al.* (2006). The in-*vitro* dry matter digestibility of culled sweet potato tuber was lower than the value reported by Gebreegziabher *et al.* (2014). Among vegetable by-products, culled tomato had the lowest IVDMD, the results of, which is higher than the value reported by Ventura *et al.* (2009).

CONCLUSION

Vegetable by-products are some of the livestock feed resources that are available and utilized in the urban and peri-urban production systems. Among vegetable by-products, potato, cabbage, sweet potato, tomato and carrot by-products are the most widely available and utilized as livestock feed, which could be used to supplement other feed resources such as hay and crop residues. Most of the vegetable by-products are available and utilized year round by urban and peri-urban livestock producers to overcome the problem of seasonal feed scarcity. However, perishability, feed safety, lack of storage facilities and awareness are some of the constraints affecting vegetable by-products utilization. Vegetable by-products are one of the most promising feed resources in terms of nutritional values and quality in the study areas. The CP contents of most vegetable by-products are above 7.5 % across locations and types of vegetable by-products in the study areas. The *in-vitro* dry matter digestibilities of vegetable by-products are above 76.82% across locations and types of vegetable by-products of the study areas. Generally, vegetable by-products could be an alternative potential source of available and frequently utilized feedstuffs. It has better nutritive values for all classes of livestock and could be considerable as potential strategic supplementations for poor quality roughages. Further research which assesses the performance of animals fed vegetable by-products is recommended.

Table 7. Chemical composition and *in vitro* dry matter digestibility (% DM) of the vegetable by-products

Location	Types of VBPs	Ash	CP	NDF	ADF	ADL	EE	IVDMD
Shashemene	Potato peels	5.11 ± 0.54[c]	12.32 ± 0.39[c]	30.59 ± 0.30[b]	11.47 ± 0.31[d]	2.42 ± 0.85[c]	1.00 ± 0.12[d]	84.19 ± 0.61[b]
	Cabbage leaf	17.64 ± 0.54[a]	18.75 ± 0.39[a]	23.39 ± 0.30[c]	16.09 ± 0.31[c]	1.41 ± 0.85[c]	1.78 ± 0.12[c]	92.61 ± 0.61[a]
	Culled sweet potato	3.23 ± 0.54[c]	3.97 ± 0.39[d]	20.49 ± 0.30[d]	12.38 ± 0.31[d]	1.55 ± 0.85[c]	1.23 ± 0.12[cd]	84.25 ± 0.61[b]
	Culled tomato	9.21 ± 0.54[b]	15.74 ± 0.39[b]	45.08 ± 0.30[a]	35.06 ± 0.31[a]	9.94 ± 0.85[a]	11.33 ± 0.12[a]	78.57 ± 0.61[d]
	Culled carrot	5.16 ± 0.54[c]	10.56 ± 0.39[c]	30.68 ± 0.30[b]	20.99 ± 0.31[b]	6.32 ± 0.85[ab]	4.96 ± 0.12[b]	80.31 ± 0.61[c]
Hawassa	Potato peels	6.80 ± 0.54[b]	10.59 ± 0.39[c]	32.50 ± 0.30[b]	13.07 ± 0.31[d]	3.11 ± 0.85[c]	1.48 ± 0.12[d]	82.79 ± 0.61[b]
	Cabbage leaf	14.33 ± 0.54[a]	18.18 ± 0.39[a]	23.50± 0.30[d]	16.75 ± 0.31[c]	1.60 ± 0.85[cd]	2.09 ± 0.12[c]	90.33 ± 0.61[a]
	Culled sweet potato	9.10 ± 0.54[b]	4.32 ± 0.39[d]	18.40 ± 0.30[e]	8.95 ± 0.31[e]	1.05 ± 0.85[d]	1.13 ± 0.12[d]	86.06 ± 0.61[b]
	Culled tomato	16.11 ± 0.54[a]	15.26 ± 0.39[b]	48.32 ± 0.30[a]	38.06 ± 0.31[a]	11.05 ± 0.85[a]	14.55 ± 0.12[a]	76.82 ± 0.61[c]
	Culled carrot	7.98 ± 0.54[b]	11.94 ± 0.39[c]	28.62 ± 0.30[c]	19.17 ± 0.31[b]	5.39 ± 0.85[b]	3.81± 0.12[b]	82.95± 0.61[b]
Yirgalem	Potato peels	10.11 ± 0.54[c]	14.46 ± 0.39[b]	27.45 ± 0.30[c]	8.61 ± 0.31[d]	1.74 ± 0.85[b]	0.89 ±0 .12[c]	86.34 ± 0.61[a]
	Cabbage leaf	15.40± 0.54[a]	17.96 ± 0.39[a]	24.23 ± 0.30[d]	18.91 ± 0.31[c]	2.11 ± 0.85[b]	2.45 ± 0.12[b]	85.41 ± 0.61[a]
	Culled sweet potato	8.68 ± 0.54[d]	5.17 ± 0.39[d]	18.28 ± 0.30[e]	8.90 ± 0.31[d]	1.09 ± 0.85[b]	0.85 ± 0.12[c]	88.08 ± 0.61[a]
	Culled tomato	11.96 ± 0.54[b]	16.61 ± 0.39[a]	40.04 ± 0.30[a]	32.12 ± 0.31[a]	8.27 ± 0.85[a]	8.51 ± 0.12[a]	80.8 ± 0.61[b]
	Culled carrot	11.81 ± 0.54[b]	10.30 ± 0.39[c]	34.46 ± 0.30[b]	23.31 ± 0.31[b]	10.51 ± 0.85[a]	2.19 ± 0.12[b]	78.89 ± 0.61[b]
Overall	Potato peels	7.34 ± 0.31 [cd]	12.46 ± 0.23[c]	30.18 ± 0.17[c]	11.05 ± 0.18[d]	2.42 ± 0.49[c]	1.13 ± 0.07[d]	84.44 ± 0.35c
	Cabbage leaf	15.79 ± 0.31[a]	18.29 ± 0.23[a]	23.70 ± 0.17[d]	17.25 ± 0.18[c]	1.71 ± 0.49[c]	2.11 ± 0.07 [c]	89.45 ± 0.35a
	Culled sweet potato	7.00 ± 0.31[d]	4.49 ± 0.23[e]	19.06 ± 0.17[e]	10.08 ± 0.18[e]	1.23 ± 0.49[c]	1.07 ± 0.07[d]	86.13 ± 0.35b
	Culled tomato	12.43 ± 0.31[b]	15.87 ± 0.23[b]	44.48 ± 0.17[a]	35.08 ± 0.18[a]	9.76 ± 0.49[a]	11.46 ± 0.07[a]	78.73 ± 0.35e
	Culled carrot	8.32 ± 0.31[c]	10.93 ± 0.23[d]	31.25 ± 0.17[b]	21.16 ± 0.18[b]	7.41 ± 0.49[b]	3.66 ± 0.07[b]	80.72 ± 0.35d
Significance	Types of VBPs	**	**	**	**	**	**	**
	Location	**	*	**	**	NS	**	NS
	Interaction	**	**	**	**	*	**	**

Means in the column with different superscripts are significantly different from each other (P<0.05), **= highly significant (P<0.001), *=significant (P<0.05), ADF=acid detergent fiber, ADL=acid detergent lignin, CP= crude protein, DM=dry matter, EE= ether extract, IVDMD= *in vitro* dry matter digestibility, NDF= neutral detergent fiber, NS=not significant, SE= standard error mean, VBPs= vegetable by-products

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