Availability of agro-industrial by-product in the Cape provinces of South Africa and a review on their potential uses in animal feed

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Abstract

The objective of the study was to identify and quantify available agro-industrial by-products (AIB) that can be used by the resource-poor livestock farmers (RPLF) residing in the three Cape provinces of South Africa; the provinces are the Western Cape, Eastern Cape and Northern Cape. Thirty-five food-producing factories, 12 in the Eastern Cape, 12 in the Western Cape and 11 in the Northern Cape were visited. Face to face, interviews with the factory managers were conducted to collect data using structured questionnaires. The results showed that the E. Cape is the highest producer of citrus pulp (± 1222 tons/week), and fruit and vegetable wastes (40 ton/week) compared to the other two provinces. Furthermore, the E. Cape is generating higher ($P<0.05$) (69 tons/week) biomass of by-products than the other two provinces. However, W. Cape had the highest ($P<0.05$) production of apple and pear pomace (154 tons/week) compared to the other two provinces. The N. Cape produces 46 tons/week of dry fruits from grapes and 75 tons/week of raisins and nuts. Some farmers around the provinces collect most of the by-products generated from the factories free (47%), 35% of which are collected by those who have contracts with the factories, 12% are sold, and the rest are either dumped (3%) or used as fertilizer (3%). Literature shows that these by-products are rich in nutrients (energy and or protein) hence they are a potential feed source. However, one major obstacle that hinders the use of these by-products as animal feeds by the RPLF is lack of transport and contract agreements from factories producing byproducts. Thus, technical assistant to the RPLF with the transport and contract agreements will allow a full exploitation of these by-products by the farmers for improved animal production and better quality products.

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Introduction

In South Africa, livestock farming plays a crucial role in sustaining the livelihood of rural communities and the development of the agricultural sector (Nkosi *et al*., 2019). However, the cost of livestock feed is increasing due to competition between humans and animals for feed ingredients, the rising fuel and fertiliser price and the constant occurrence of extreme weather conditions such as the 2016 drought (De Evan *et al*., 2019, Thomas *et al*., 2018).

During drought, resource-poor livestock farmers (RPLF) are faced with fluctuating quantity and quality of the feed supply resulting in reduced profitability (Arowolo & He, 2018; DAFF, 2017). Consequently, during the 2016 drought, the Department of Agriculture, Land Reform and Rural Development (DALRRD) and local municipalities were compelled to supply fodder (hay/bales) to the RPLF as part of the drought fodder relieve program (DAFF, 2018). This was done to improve fodder flow in order to sustain livestock production during the drought period. Consequently, a search for alternative available feed resources was instigated to improve fodder flow for livestock farmers in the three Cape provinces. Many nutritionists have reckoned the use of agro-industrial by-products in animal feeds as a means for reducing cost of feeding (Valenti *et al*., 2018, Nkosi & Meeske, 2010). Using these by-products in animal feeds will assist the food producing factories to reduce disposal costs while minimising the environmental impacts that these by-products would otherwise create (Arowolo & He, 2018; DAFF, 2017).

According to Dr Motiang (personal communication, 28 February 2020, Agricultural Research Council – Animal Production, Irene), the Kaonafatso ya Dikgomo (KYD) scheme of the Agricultural Research Council has recorded 2 200, 960 and 369 emerging beef farmers for the year 2018 in the Eastern Cape (E Cape), Northern Cape (N Cape) and the Western Cape (W Cape) provinces, respectively. These farmers are struggling to obtain animal feed resources for their cattle, especially during the winter or drought seasons. The three Cape provinces have a high number of food processing factories, particularly for juice and wine production.

The production of food from fruit and fresh vegetables in these provinces yields numerous tons of by-products, which include fruit pulps, vegetable wastes, and fruit raisins. These by-products have been reported to contain nutrients (e.g. energy and protein) that can be beneficial to animal production under both commercial and smallholder farmers. However, there is lack of information on the period of availability, yield and current uses of the agro-industrial by-products produced in these three provinces of South Africa. This study aimed at creating awareness to emerging farmers and government officials about the availability, quantity and quality of the agro-industrial by-products that can help to solve their feed shortage problems, especially during drought and winter months. Therefore, the main objective of this study was to identify and quantify the availability of fruit and vegetable by-products in the three Cape provinces and the challenges thereof.

Methodology

Study area and data collection

The study was conducted in the three Cape provinces (i.e. Western Cape, Eastern Cape and Northern Cape) of South Africa from June to December 2019. These provinces vary in climatic condition, which could have an impact on the kind of agro-industrial by-products produced as well as livestock production systems practised in each of the provinces. Western Cape is classified as Mediterranean, with warm, dry summers and mild and moist winters; Eastern Cape is classified as a province with two climatic conditions; Mediterranean on the borders of Western Cape and subtropical towards KwaZulu-Natal (KZN). Thus, the province receives rain throughout the year, particularly in the areas along the coast. The Northern Cape is classified as semi-arid province with temperature fluctuating between two extremes, very hot in summer and cold with occasional frost in winter. A survey was conducted from factories producing wine, fruit juice, dry fruits and nuts in these provinces.

Data was collected from the food-producing factories using a structured questionnaire, which were completed through face-to-face interviews with the factory managers. All agro-industrial by-products that were available in the three Cape provinces were recorded and a literature review on their nutritive value and performance of livestock when fed these by-products as supplements.

Ethical clearance

The names of the respondents and that of farmers/dealers that have contracts with the food producers were not disclosed. The respondents were notified verbally that they could abstain from responding to uncomfortable questions.

Data analysis

The quantitative data collected were analysed using a descriptive (frequency distribution, averages/mean, and mode scores) statistics (Gerber-Nel *et al.,* 2005) by Statistical Package for Social Sciences (SPSS) version 20.0 for Windows. Agro-industrial by-product yields generated by food producing companies are reported as means with standard deviations.

Results and Discussion

Biomass generated

A total of thirty-five food-producing factories (i.e. 12 for Eastern Cape, 12 for Western Cape and 11 for Northern Cape) were visited, and data on the seasonal availability of the agro-industrial by-products is shown in Table 1. Pomaces from apple and pear are available in the Western and Eastern Cape provinces from May to October, while that from grapes and strawberries are available in all the three provinces from April to September, which are winter months. Livestock production under emerging beef farmers is low due to lack of quality feeds during these periods. Three factories (2 in the Western Cape, i.e. Bellville and Elgin districts, and 1 in the Eastern Cape, Port Elizabeth) produce pomaces from apple and pears (Table 2). In addition, nine factories [4 in Western Cape (i.e. Cape Town, Ceres, George and Elgin districts), 4 in Port Elizabeth, Eastern Cape and 1 in Kakamas, Northern Cape)] produce citrus pulp. Five factories [3 in Western Cape (i.e. Paarl, Bellville and Elgin districts) and 2 in Northern Cape (i.e. Kanoneil and Keimoes)] produce grape pomace. The Eastern Cape has 7 factories in the Buffalo city municipality that produce fruit and vegetable by-products, while there is one factory in the Western Cape (i.e. George) that produces the fruits and vegetable by-products.

The Northern Cape, however, has four factories that produces dry fruits (Keimoes, Kanoneil, Kakamas and Upington), and four factories (Prieska, Hartswater, Upington and Kakamas) that produces raisins and nuts by-products. According to Dr Motiang (personal communication), most of the emerging beef farmers are residing around these areas and could benefit from the availability of these by-products.

Although the availability of agro-industrial by-products produced from the three Cape provinces is seasonal April to October, fruits and vegetable residues are available throughout the year. Therefore, these by-products are available during the period of feed scarcity where animals are starving for feed. Hence, this allows the RPLF to have alternative feed resources for their livestock during the winter periods. By-products such as fruit pulps/pomaces derived from the juice/wine-producing factories consist of peels, seeds, inside residue and culled fruits (Sharif *et al*., 2018). Due to the high transportation cost, seasonal availability and perishability, the use of these by-products as feedstuffs on as-is basis, might pose negative health issues to livestock (Sharif *et al*., 2018). Thus, these by-products should be conserved by either drying or ensiling, but the former is costly to the RPLF since machinery suitable for drying is required (Nkosi *et al.,* 2018).

Table 1 Availability of agro-industrial by-products in the Cape provinces

By-products	Province	Availability Period
Apple and pear pomace	Western Cape	May to October
	Eastern Cape	May to October
Citrus pulp	Western Cape	April to September
	Eastern Cape	April to September
	Northern Cape	April to September
Dry fruits	Northern Cape	April to October
Raisin and popped nuts	Northern Cape	April to October
Fruit and veg	Eastern Cape	Throughout the year
	Western Cape	Throughout the year
Grapes pomace	Western Cape	April to October
	Northern Cape	April to October
Strawberry pomace	Western Cape	April to September

Table 2 Number of factories generating the agro-industrial by-products in the Cape provinces

	Province		
By-products	**Western Cape**	**Eastern Cape**	**Northern Cape**
Apple and pear pomace	2	1	-
Citrus pulp	4	4	1
Grape pomace	3	-	2
Strawberry pomace	2	-	-
Fruit and veg	1	7	-
Dry fruits	-	-	3
Raisin and popped nuts	-	-	5
Total	**12**	**12**	**11**

EC: Eastern Cape, NC: Northern Cape, WC: Western Cape

Table 3 The agro-industrial by-products total biomass (tons/week) generated in the Cape provinces

Province	Mean ± SD
Western Cape	$56.8^{b} \pm 55.3$
Eastern Cape	$68.6^{a} \pm 141.9$
Northern Cape	$2.9^{c} \pm 2.2$

$^{a, b, c}$ means with different superscripts differ significantly (P<0.05) SD: standard deviation

The Eastern Cape generates high ($P<0.05$) quantity of by-products, followed by the Western Cape (Table 3). The high quantity of the by-products in the Eastern Cape was contributed by the production of citrus pulps, which yields 1200 tons/week (Fig 1). The Northern Cape generated less than 200 tons/week of citrus pulps, while fruits and vegetables generated in the Eastern Cape yielded 40 tons/week. The Western Cape had the higher ($P<0.05$) production of apple and pear pomaces compared to other provinces (Fig 1). The production of these pomaces were 154 tons/week in the Western Cape and 120 tons/week of grape pomace in the Eastern Cape, respectively. The Northern Cape is rich in by-products from dried fruits, which are produced in the Keimoes, Kanoneiland, Kakamas and Upington areas. In contrast, by-products from raisins and popped nuts are produced in the Prieska, Hartswater, Upington and Kakamas areas. The production of dry fruits was at 46 tons/week and that of raisins and nuts residues were at is 72 tons/week.

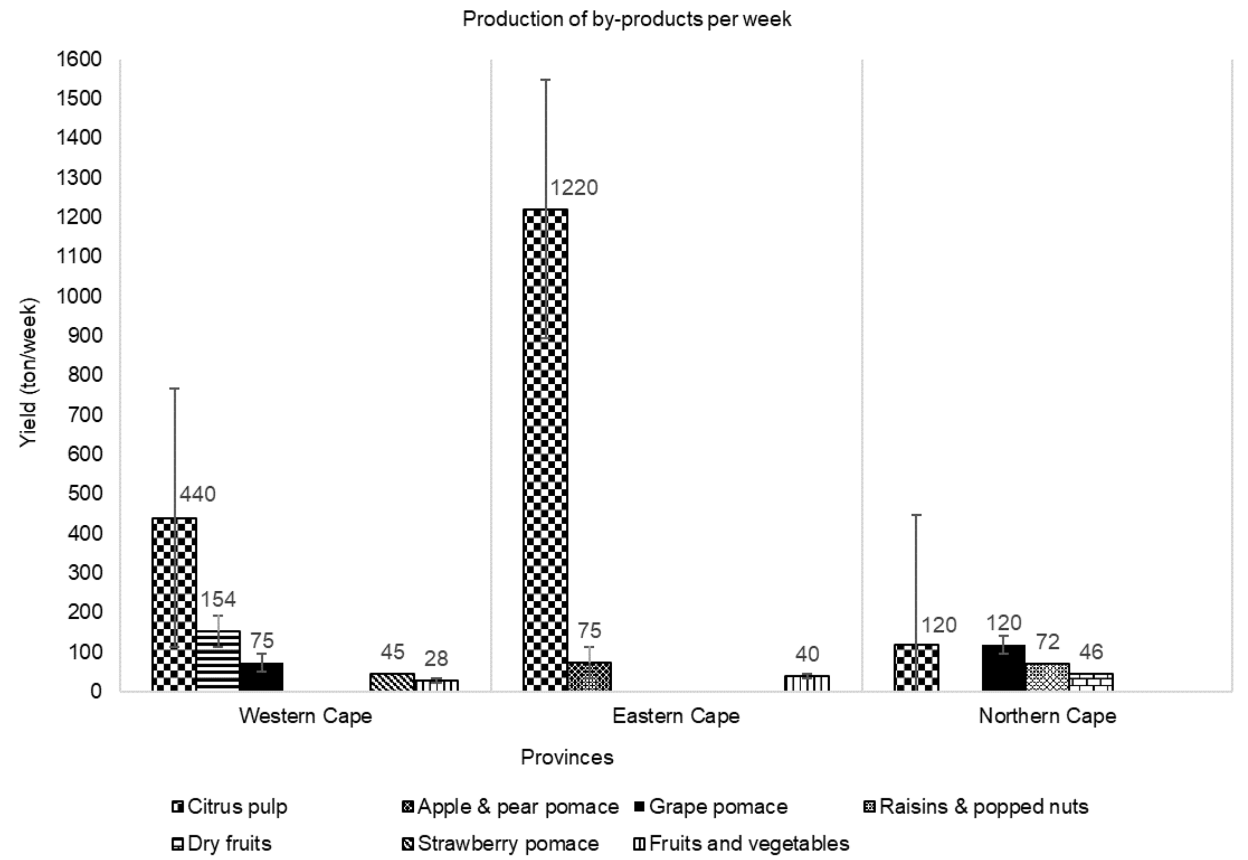

Figure 1 Individual by-products biomass (ton/week) generated per province

P: Probability value, R^2: Co-efficient of determination (demonstrates how close the data are to the fitted regression line around its mean)

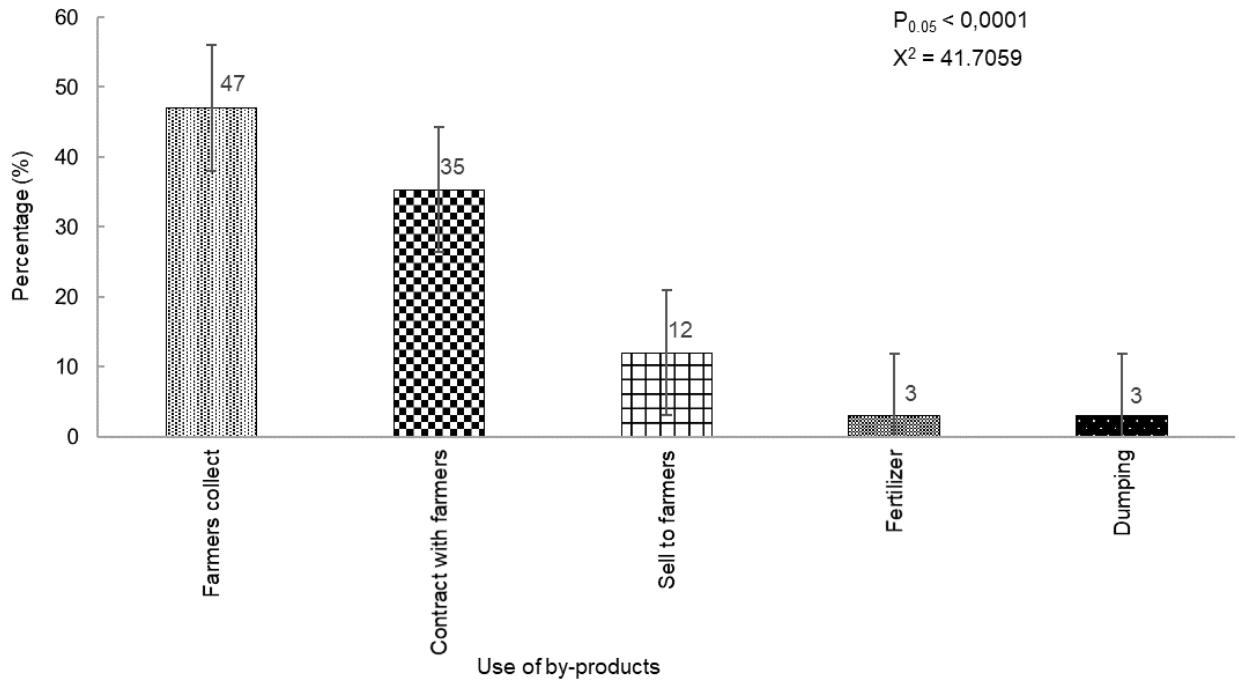

Figure 2 The use of all the generated by-products biomass combined

P: Probability value, X^2: Co-efficient of determination (demonstrates how close the data are to the fitted regression line around its mean).

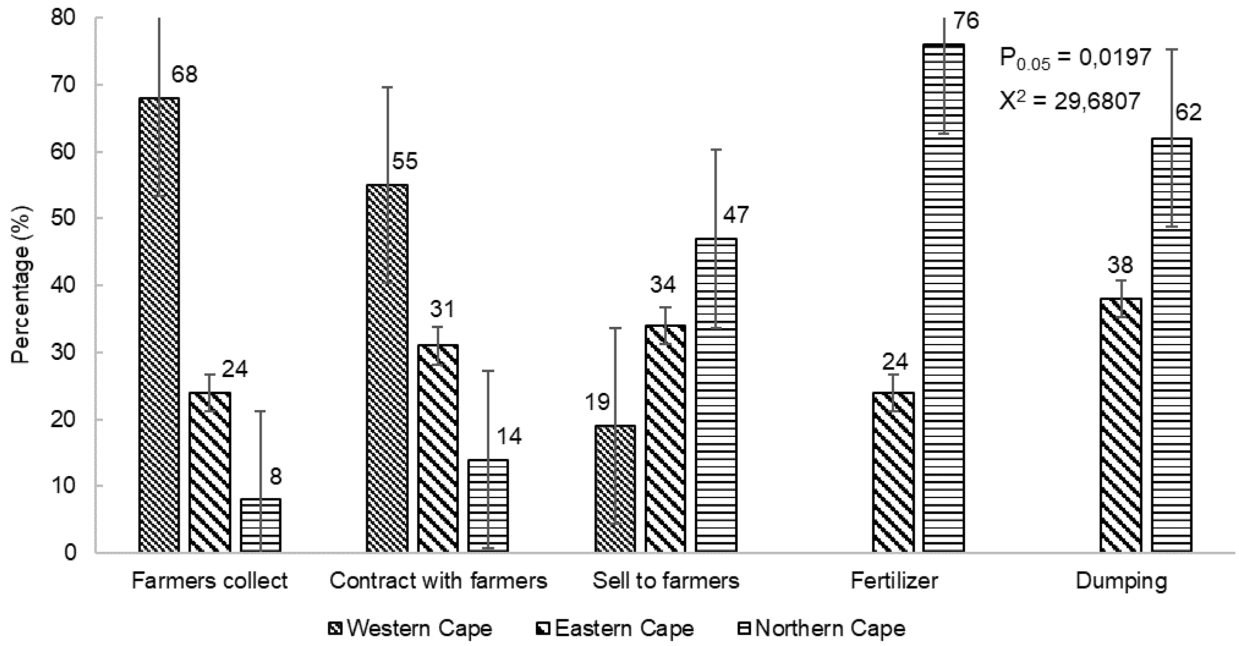

Figure 3 The use of the generated by-products biomass per province

P: Probability value, X^2: Co-efficient of determination (demonstrates how close the data are to the fitted regression line around its mean).

Uses of the agro-industrial by-products

The local RPLF use most of the by-products that are generated by the factories to feed animals. The farmers processed these by-products in the form of pellets, meal and silage to feed their animals. This is in line with the South African Animal Feed Act (Act 36, 1947), which strongly restricts the use of agro-industrial by-products as either feed ingredients or sole feed without prior processing. The processing of by-products assists to minimize the chances of transmitting pathogens that may survive during the contamination of agro-industrial by-products, which may adversely affect the well-being of the animals.

Most factories (47%) reported that farmers collect by-products for feeding their livestock (Figure 2). Sometimes, the owners of the food producing factories, who have livestock farms, also use the by-products to feed their animals. However, 35% of the factories have contracts with commercial farmers to collect the by-products. These farmers collect the by-products on a daily basis until the end of the production season. There are very few (12%) factories that sell their by-products to farmers, while 3% of them use the by-products as fertilisers and the other 3% dumps the by-products in landfills. The factories that mostly use by-products as fertilisers or dumping them were dominant ($P<0.05$) in the Northern Cape relative to other provinces (Figure 3). This could be attributed to the fact that the farming system in the Northern Cape is extensive commercial livestock farming system (Jordaan *et al.*, 2013), and the province is in the arid area with less soil fertility (Du Plessis, 2016). With approximately 1,728 million tons of agro-industrial by-products being produced globally (FAO, 2014); it is laborious to dispose of these by-products due to their high moisture content (Wang *et al.,* 2014), which sometimes leads to environmental pollution (Scano *et al.*, 2014). Subsequently, the processing and use of the agro-industrial by-products as potential feed ingredients will mitigate the disposal labour and environment associated pollutions.

A review on the potential of agro-industrial by-products as feed components in livestock production

The current study reviewed agro-industrial by-products found in the Cape provinces in terms of their nutritive values and their effects on livestock performance. Apple pomace is a residue from apple processing industry, which results to 25–30% apple waste, and it constitutes of apple skin, stem, seeds and pulp discarded as waste (Ajila *et al.,* 2015; Skinner *et al.,* 2018). Apple pomace residues are rich in dietary fibres and phytochemicals, such as polyphenols (Gazalli *et al.,* 2014; Ajila *et al.,* 2015). This by-product contains 1 64 g/kg (as is basis), 45.4 g CP/kg DM, 383.5 g NDF/kg DM and 39.1 g EE/kg DM (Kara *et al.*, 2018, Proskina *et al*., 2014, Rodrigues *et al*., 2008). When dried, this by-product contains 836.5 g/kg (as is basis), 62.2 g CP/kg DM, 26.3 g EE/kg DM, and 473 g NDF/kg DM, (Pirmohammadi *et al*., 2006, Juskiewicz *et al*., 2015). Polyphenols compounds of apple pomace include total phenols 6.9 g/kg, total flavonoids 0.8 g/kg and total flavan-3-ols 6.2 g/kg (Ćetković *et al.*, 2008). Owing to the presence of phytochemicals; therefore, apple pomace has antioxidant effects (Ćetković *et al*., 2008). The antioxidant effects in pomace might have health benefits (Gazalli *et al*., 2014). In addition, apple pomace can be used as energy source since it contains metabolisable energy (ME) of 10.9–11.7 MJ/kg DM (Islam *et al*., 2018). However, apple pomace contains low levels of crude protein (< 5%) and according to van Soest (1994), feed resources that contain less than 70 g CP/kg DM are not able to support optimum rumen fermentation and may result in depressed feed intake. Therefore, feeding apple pomace to animals will required protein supplementation. Dietary substitution of maize with 100 g/kg of dried apple pomace did not adversely affect the growth performance of broilers (Kara *et al.*, 2018; Pirmohammadi *et al.*, 2006). However, increasing the inclusion levels of dried apple pomace depressed feed efficiency in ewes, probably due to higher fibre content (Islam *et al.*, 2018). Matoo *et al*. (2001) reported improved broiler performance when diet containing apple pomace was supplemented with a commercial enzyme preparation (α-amylase, hemicellulase, protease and β-glucanase) compared to diets fed without enzyme addition. Juśkiewicz *et al.* (2015) reported that feeding 50 g/kg of apple pomace to turkey did not affect growth performance and post-slaughter parameters of young turkeys. Furthermore, feeding 50 g/kg of fermented apple pomace reported to significantly improve the efficiency of feed conversion from 55.4 to 92.1% on growing pigs (Ajila *et al*., 2015). On the other hand, meat quality was significantly improved by reducing total cholesterol by 124 g/kg and colour value by 960 g/kg when 100 g/kg of dried apple pomace was fed to finisher pigs (Pieszka *et al*., 2017). In addition, feeding 110 g/kg of fermented apple pomace to sheep was reported to improve the nutritional quality of meat by reducing lipid oxidation, which normally results in rancidity (Alarcon-Rojo *et al.*, 2019).

Citrus pulp, a residue from citrus fruit juice extraction, contains 492 to 692 g fresh citrus fruit/kg with 600 – 650 g/kg DM of peels/ (Alnaimy *et al.*, 2017). When dried, citrus pulp (DCP) contain 71.5 g CP/kg DM, 38 g EE/kg DM, 140 g CF/kg DM and 57.5 g ash/kg (Alnaimy *et al.,* 2017), with 231 g ADF/kg DM and 259 g NDF/kg DM (Belibasakis & Tsirgogianni, 1996). This by-product has metabolisable energy (ME) that ranges between 13.4–14.0 MJ/kg DM (Wing, 2003); hence, it can be used as an energy source feed. Feeding 200 g DCP/kg did not affect milk yield in dairy cattle (Fegeros *et al*., 1995; Assis *et al*., 2004). However, a significant decrease in milk yield was reported in dairy cows that were fed diets containing 250 to 750 g/kg of DCP (Steyn *et al*., 2017). Feeding Angus steers with a diet that contained 150 g/kg of DCP exhibited improved growth performance and carcass traits (Tayengwa *et al*., 2020). Steyn *et al*. (2017) replaced maize grain with DCP (660g/kg) in the diet of Jersey cows grazing ryegrass pasture and reported an increase in the milk protein and lactose content. However, milk yield was reduced with DCP inclusion, but the cows maintained a healthy rumen environment. The high fibre content and the presence of limonin (toxic to monogastric animals) in the seeds disqualified the feeding of DCP to pigs and poultry (Gohl, 1982). However, Crosswhite *et al*., (2013) fed a diet that contained 150 g/kg of DCP to pigs and reported improved carcass traits, meat quality and sensory characteristics. This means that higher dietary inclusion of > 150 g/kg of DCP in pig diets will be problematic.

Grape pomace (GP), a residue from the processing of grapes for ethanol, fruit juice and wine production, contains discarded grapes, stems, skins, seeds and peels (Llobera & Canellas, 2007). Dried grape pomace (DGP) contains 915 g DM/kg, 119 g CP/kg DM, 330 g Ash/kg DM, 70 g EE/kg DM, 33.9 g/kg of total polyphenols and 18.4 MJ/kg DM (Ebrahimzadeh *et al*., 2018, Nkosi *et al.,* 2019). In addition, this by-product contains 123 to 146 g/kg of condensed tannins (Foiklang *et al*., 2016), which can be beneficial when fed to ruminants for methane reduction and improvement in carcass quality (Mlambo & Mapiye (2015). The presence of polyphenols in this by-product indicates that it has antioxidants effects (Llobera & Canellas, 2007). The fibre content in this by-product is reported at 475 g NDF/kg DM and 306 g ADF/kg DM (Foiklang *et al*., 2016; Nkosi *et al*., 2019). Feeding 100 g/kg of DGP to broiler chickens did not affect the growth performance, but had a tendency of increasing immune responses, while significantly reduced the villus height crypt depth in the jejunum (Ebrahimzadeh *et al*., 2018). Supplementing layers by 40 g/kg of DGP was reported to increase egg weights (Kara *et al.*, 2015). Supplementation of diets with 20 g/kg of DGP improved rumen fermentation efficiency, digestibility and microbial protein synthesis in steers (Foiklang *et al*., 2016). However, supplementation of DGP above 100 g/kg in growing lambs decreased animal performance due to the high dietary tannin brought by the DGP in the diet (Calderón-Cortés *et al*. 2018).

Strawberry pomace (SP), a residue that remains after juice processing, contains about 4% of fresh strawberry fruit of the total mass, stems, skins, seeds and peels (Šaponjac *et al.,* 2015). This by-product is reported to contain 166 g CP/kg DM (Juskiewicz *et al.,* 2015) and high total polyphenols that range from 12.5 to 23.4 g/kg (Castrica *et al*., 2019), making it a therapeutic feed source to animals (Djilas *et al.,* 2011). However, polyphenolic compound can also limit the utilisation of this by-product as animal feed unless treating it with polyethylene glycol (PEG). However, dietary inclusion of 50 g/kg of SP did not have an adverse effect on growth performance, and carcass characteristics of growing turkey (Juskiewicz *et al.,* 2015). Supplementation of 10 g/kg of SP to finisher pigs improved the n-3 polyunsaturated fatty acid, particularly n-3 PUFAs composition in muscle, and reduced cholesterol level (Pieszka *et al.,* 2017).

Raisin by-products are residues that remain after machinery cleaning, sorting or packaging of sun-dried raisins (Saremi *et al*., 2014). According to Yari *et al*. (2015a), these by-products are produced from the outer layers of the flesh, skin and pedicle of barriers, un-ripped and abnormal barriers, and peduncles and rachises with branches of grapevines. Since these by-products are made up of various leftovers and different cultivars, the nutrient content varies. According to Yari *et al*. (2015b), these by-products contain ME that ranges from 7.5 to 8.4 MJ/kg DM, organic matter digestibility ranging from 501 to 560 g/kg DM. Additionally, the by-products contain tannins in the range of 34.6 to 75.8 g/kg DM (Souri *et al*., 2015; Yari *et al*., 2015a). Saremi *et al*. (2014) supplemented 200 g/kg of raisin in the diets of growing lambs. They reported a reduction in protein digestibility, nitrogen retention and absorption of the nutrients by the lambs. However, mixing these by-products with urea, molasses and polyethylene glycol improved feed intake, dry matter digestibility, daily gain and nitrogen retention in sheep (Souri *et al.,* 2015).

Fruit and vegetable wastes from fresh produce markets consist of various market wastes that are dumped in one bin to be taken to a dumping site. These wastes may contain tomato pomace/wastes, cabbage, carrot, spinach, onions, etc. The nutritive values of these wastes may vary due to the nature of the wastes dumped.

Das *et al*. (2019) blended vegetables (cucumber, bitter gourd, spotted gourd, brinjal, pumpkin, potato, tomato, ladies finger, and snake gourd) wastes. They reported that the vegetable waste (VW) did not improve DM intake, digestibility, growth performance and health status of bulls at 300 g DM/kg inclusion level.

Nkosi *et al*. (2010) studied the dietary inclusion of discarded cabbage and reported that increasing the cabbage supplementation caused small and progressive depressions in DM intake, digestibility and growth rates of lambs. According to Nkosi & Ratsaka (2010), beetroot (*beta Vulgaris var*.) contains 142 g DM/kg, 149 g CP/kg DM, 12.8 MJ ME/kg DM and 87% *in vitro* organic matter digestibility (IVOMD). These researchers fed growing lambs on diets that contained 150 g/kg of shredded beetroot and reported no adverse effect on growth performance. Tomato pomace (TP), a residue that remains after the production of tomato juice or tomato paste, contains 45 g/kg DM of the total weight of fresh tomato, peels and seeds (Mirzaei-Aghsaghali & Maheri-Sis, 2008), with 250 g DM/kg, 210 g CP/kg DM (Abdollahzadeh *et al*., 2010). Yitbarek, (2019) included 20 g/kg of dried TP in the diets of broilers and reported no effect on the DM intake and growth performance of chickens. Omer & Abdel-Magid (2015) fed diets that contained 15 g/kg of dried TP and reported improved growth performance in sheep. The inclusion level of 100 g/kg of TP improved the DM intake and digestibility, boosted milk vitamin A, E and C contents and improved immune function in early lactating dairy cows (Tuoxuniang *et al.,* 2020). Popped nuts, is a by-product that results from the popping of nuts to produce snacks. This by-product is produced in the Northern Cape of South Africa and is sold to farmers at R0.50 c/kg. However, there is currently no information about its nutritional content, which warrants further research.

Challenges and recommendations

Based on the discussion we had with some of the factory managers, the by-products can be available to the emerging livestock farmers provided they have transport to collect the by-products from the factories daily as per the waste management law. In addition, there are challenges and possible solutions for the RPLF to access these by-products. These include:

i) The moisture content of the by-products – most by-products contain > 80% moisture, which makes them perishable and difficult to handle, transport and store. Farmers that are staying in close proximity to the factories are the ones who should benefit in the use of these by-products for livestock feeding
ii) Processing facility – the by-products should be processed by either drying or ensiling before feeding to animals. This is in line with the South African law (Act 36, 1947) which prohibits the feeding of unprocessed by-products to livestock since this may lead to the transmission of pathogens to the animals. Building a drying facility closer to the production factory will reduce the transportation cost and preserve the materials. However, this is a costly exercise since emerging farmers do not have funds to build such a facility.
iii) Transportation – the emerging farming sector lacks transport to collect the by-products from the factories to their farms.
iv) Contract agreements – it should be noted that there is currently no emerging farmer who has a contract to collect the by-products from these factories. Government departments should negotiate contracts with the producing factories that would allow the emerging farmers to collect the by-products.
v) Ration formulation – animal nutritionists, should assist the emerging farmers with cost-effective ration formulations. This will help farmers on how to use the by-products effectively without negative impacts on the animals fed.

Conclusions

The Eastern Cape and Western Cape are producing a high quantity of agro-industrial by-products. While commercial farmers already have contracts for collection of these by-products from the factories, most of the RPLF are struggling due to transportation issues, thus could not enter into contracts with factories to collect the by-products frequently. Most by-products that are produced in the three Cape provinces are available during the winter months when forage pasture is scarce and dry with low nutrient value, which are the challenging periods in meeting nutrient requirements of the animals. Furthermore, although the moisture content of the by-products is worrisome, the nutritive values of the by-products are comparable to those of other conventional by-products that are currently used in the feed industry. Thus, the RPLF who are residing in proximity to the food-producing factories have the benefits to access the by-products and use as feed, provided the aforementioned recommendations are followed. Further studies on preservation and future research basic studies (Laboratory work) and on utilization (feeding studies) in South African content is warranted.

Table 4 Chemical composition of dried by-products and performance of animals

	Chemical composition (%)									
By-Product	DM	CP	CF	EE	ADF	ADL	NDF	GE MJ/kg DM	ME MJ /kg	Reference
Apple pomace	92.4 (14.9)	6.6	22.0	2.6	-	-	56.5	-	-	Juśkiewicz *et al.* (2015)
		4.5	22.1	3.9	30.2	12.9	38.3	-	-	Kara *et al.* (2018)
	74.9 (14.8)	6.4	-	-	40.5	1.0	47.3	-	-	Pirmohammadi *et al.* (2006)
		3.9	16.1	0.28	26.8		36.9	-	-	Proskina & Cerina (2014)
Citrus pulp	90 (8.6)	6.9	14	3.8	23	-	-	-	-	Alnaimy *et al.* (2017)
		6.5	-	2.7	10.0	2.1	15.5	-	-	Tayengwa & Mapiye (2018)
	86.3 (18.3)	4.8	-	1.8	14.6	0.6	85.4	-	11.1	Tayengwa *et al.* (2020)
		6.6	12.6	3.3	16	-	-	-	-	Alnaimy *et al.* (2017)
	90.5 (15.9)	6.5	-	3.7	14.3		20.6	-	-	Sharif *et al.* (2018)
		14.3	7.5	-	12.0	1.0	27.5	-	-	Piquer *et al.* (2009)
Grape pomace	89.9 (26.4)	11.1		7.4	31.8	20.6	68.2	-	8.2	Tayengwa *et al.* (2020)
		8.0	-	8.5	18.9			16.9	-	Castrica *et al.* (2019)
	87.6 (26.4)	10.3	25.0	5.1	52.3		58.0	-	19.1	Taranu *et al. (*2017)
		12.7	-	5.5	50.2			18.9	-	Chedea *et al.* (2017)
	88.4 (19.7)	6.4		11.2	25.5		25.9	-	-	Christman (2018)
		7.1	-	6.3	16.8	1.9	-	-	-	Mamma & Christakopoulos (2014)
Strawberry pomace	93.2 (7.0)	7.4	11.7	0.9	24.2	15.8	32.3	35.1		Waly *et al.* (2015)
		7.7	-	1.5	9.7	5.7	12.8	16.9	-	Castrica *et al.* (2019)
		16.4	31.4	10.4	-	-	62.9	-	-	Juśkiewicz *et al.* (2015)
Pear pulp	11.8	4.3		0.1			22.9		5.7	Marino *et al.* (2010)
Tomato pomace	91 (7.7)	21.1	29.3	9.2	40.93	22.1	65.2	-	-	Omer & Abdel-Magid (2015)
		20.8	-	0.21	-	-	37.1	-	5.1	Marino *et al.* (2010)
Ripped raisin	96.1	5.4	-	2.8	19.9	-	25.2	-	-	Yari *et al.* (2015)
Raisin stalks	96.2	8.3	-	2.3	35.5	-	53.0	-	-	Yari *et al.* (2015)
Raisin skin	96.4	4.6	-	3.9	10.1	-	12.6			Yari *et al.* (2015)
Beetroot	14.2	14.9	8.1	0.7	-	-	-	-	1.3	Nkosi & Ratsaka (2010)
Cabbage	825 (14.7)	18.4	-	15	23.6	5.5	35.2	-	12.2	Nkosi *et al.* (2016)
	10.2	18.7	-	0.51	-	-	20.9	-	10.1	Marino *et al.* (2010)
Spinach	7.7	33.8	-	0.42	-	-	37.0	-	7.9	Marino *et al.* (2010)
Lettuce	5.7	28.6	-	0.24	-	-	25.6	-	8.9	Marino *et al.* (2010)
Carrot	9.9	5.7	-	0.25	-	-	11.9	-	9.4	Marino *et al.* (2010)
Onion	10.0	12.2	-	0.10	-	-	13.8	-	10.9	Marino *et al.* (2010)

DM: dry matter; CP: crude protein; EE: ether extracts; GE: gross energy; NDF: neutral detergent fibre; ADF: acid detergent fibre; ADL: acid detergent lignin, Values in brackets are on wet basis

Conflict of interest

The authors declare that there is not conflict of interest.

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