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TECHNICAL NOTE

COMPONENTS OF CITRUS PULP WASTE (EUREKA LEMON AND CLEMENTINE) AND YELLOW MAIZE COMMONLY USED AS LIVESTOCK FEED BY SOUTH AFRICAN FARMERS

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ABSTRACT

Citrus is one of the most extensively grown fruits in several parts of the world. Therefore, its industrial processing produces large amounts of pulp waste. This study was aimed at assessing the nutritive as well as mineral components of citrus pulp waste of Eureka lemon and Clementine from two *Citrus* farms while drawing potential comparisons with yellow maize for livestock feed. Proximate analyses were done using approved/standard analytical methods of the Association of Official Analytical Chemists (AOAC), while the mineral constituents were analysed using an inductively coupled plasma optical emission spectroscopy (ICP-OES). Proximate evaluation revealed that Eureka lemon and Clementine pulp waste contained comparable amounts of fibre and lipid, and significantly higher protein contents than yellow maize. Meanwhile, minerals including Ca, Mg, K, Na, Zn, Cu, Mn and Fe were significantly higher in the citrus lemon pulp waste than in yellow maize. The study therefore points out that the *Citrus* pulp waste have the potentials to be put to more relevant livestock nutritional use.
Additional keywords: Mineral and proximate analysis, nutritional components, *Zea mays*

RESUMEN

Residuos de cítricos (limón Eureka y Clementina), y maíz amarillo como alimento del ganado de agricultores sudafricanos

Los cítricos representan uno de los frutales más extensamente cultivados en varias partes del mundo, y su procesamiento industrial origina gran cantidad de desechos de pulpa. Este estudio tuvo como objetivo evaluar los componentes nutritivos y minerales de los desechos de cítricos de limón Eureka y Clementina de dos fincas productoras, y establecer comparaciones del potencial nutricional con el maíz amarillo para la alimentación animal. Los análisis proximales se realizaron utilizando métodos analíticos estándar de la Asociación de Químicos Analíticos Oficiales (AOAC), mientras que los constituyentes minerales se analizaron mediante espectroscopia de emisión óptica de plasma acoplado inductivamente (ICP-OES). La evaluación proximal reveló que los desechos de pulpa de Clementina y limón Eureka contenían cantidades comparables de fibra y lípidos, y contenidos de proteína significativamente más altos que el maíz amarillo. Por su parte, los minerales Ca, Mg, K, Na, Zn, Cu, Mn y Fe fueron significativamente más altos en los desechos de pulpa de limón cítrico que en el maíz amarillo. Se concluye que los desechos de pulpa de cítricos tienen el potencial de ser destinados a un uso nutricional ganadero más relevante.
Palabras clave adicionales: Análisis mineral y proximal, componentes nutricionales, *Zea mays*

INTRODUCTION

Citrus fruits, including oranges, lemons, limes, tangerines, and mandarins, remain one of the most extensively grown fruits globally. The production of citrus is increasing annually, due to the consumer demand. Citrus farms and their agro-allied processing industries generate massive amounts of wastes annually. Citrus waste are partly the unwanted/un-used materials obtained from farms and agro-allied industries.

South Africa is one of the four major exporters

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of citrus and its by-products. This invariably suggests that tons of waste are generated in the process, and may sometimes be discarded into the environment. Van Dyk et al. (2013) reported that more than 50 % of citrus fruit produced from South Africa goes into waste. The waste from citrus may cause several potential environmental problems because of its fermentability if not properly converted to environmentally friendly value added products (Khan et al., 2015). Leachate from citrus waste is acidic, with high biochemical oxygen demand (BOD) and chemical oxygen demand (COD), high turbidity, total suspended solid and high nutrient such as nitrogen and phosphorus.

Citrus waste can be harvested globally on a massive and large scale of land, thus giving rise to about 50-60 % sum total of its production level and industrial significance (Satari and Karimi, 2018). Citrus waste is of enormous economic worth as it contains plenty of various biologically active compounds including carotenoids, flavonoids, dietary fibre, essential oils, polyphenols, and ascorbic acid, as well as substantial amounts of some trace elements, vitamins and minerals which could be medicinal in nature for animals. It also contains high levels of sugars suitable for fermentation for bioethanol production (Varmie and Thakur, 2021).

Currently, the need to source for other alternative feedstuff to boost livestock husbandry is increasing in most countries, especially in developing countries. This is because conventional animal feedstuffs are often expensive, and most farmers in those countries (South Africa inclusive) may not be able to afford them; therefore, the utilization of agro-industrial by-products (as feedstuffs) from farms and industries may be economically worthwhile. The current volume of citrus waste frequently gotten as by-products from citrus farms could be useful in cementing the nutritional gap experienced in animal feed and avoiding the competition for edible grains consumption such as yellow maize.

Conversely, there is merit in assessing its use as an unconventional feed source in South Africa as it could proffer an alternative to yellow maize for farmers, judging from the constant hike in price of grains, including maize. The objective of this study was to determine the nutritional and mineral values of Eureka lemon and Clementine pulp waste as a potential feed resource as compared to yellow maize, a commonly used livestock feed by local farmers in South Africa. The nutritive characteristics of these dried citrus pulp waste were compared with the qualitative parameters of yellow maize.

MATERIALS AND METHOD

Maize sample procurement. The yellow maize used in this study was obtained from a common agro-allied store in the Alice location, where most local farmers purchase yellow maize. It is located in the Raymond Mhlaba local Municipality (Amathole District) of the Eastern Cape Province, South Africa. A popularly known grain is the Okavango flint maize with big kernels that are dent to flint.

Collection of citrus waste. Citrus meant to be discarded as waste by two major commercial citrus farms, located in the Eastern Cape Province of South Africa, were collected and kept in plastic bags within 24 hours of collection at room temperature before further processing in the laboratory. The samples included Clementine (C) and Eureka Lemon (EL) from Nandeshook farm (F1) and Greenwood farm (F2).

Nandeshook farm is located in an area with short and warm summers, and long, cool and windy winters, with temperatures typically varying between 10 and 26 °C. Meanwhile, in the Greenwood farm area, the summers are hot and winters short and cold; it is wet and partly cloudy year round. The temperature typically varies from 5 to 32°C (GSSA, 1970). Main soil characteristics of both farms were similar.

Preparation of citrus pulp for analysis. The waste citrus fruits were first peeled manually before they were cut into sampler sizes, and manually drained to remove excess liquid from them. Afterwards, the citrus wastes were spread on flat clean surfaced platforms (wooden materials) and air-dried (solar drying) till the liquid in them were considerably removed. After air-drying, the *Citrus* pulp waste were then oven-dried at a temperature of 50 ^{o}C for 48 hours in order to obtain the desired dried matter, and to evade high temperature-induced loss of volatile secondary metabolites. The dried citrus pulps were then pulverised into fine particles using a

blender. The pulverised materials were then neatly packed into plastic bottles and kept in cool conditions, before carrying out further analysis.

Experimental analysis of nutritive composition of *Citrus* pulp waste. The moisture content was determined following the description of AOAC (2000). The ash content was obtained by use of the dry ashing technique as was described by Agrilasa (2007).

The crude protein estimation was calculated from the total nitrogen content in the sample, as was explained in the micro Kjeldahl procedure (Hussain et al., 2011). The dietary fibre content was obtained out using the modified acid-base digestion approach as was described by Aina et al. (2012). The crude lipid (fat) was determined using the Soxhlet extraction method as was described by Al-Harrasi et al. (2012). The total carbohydrate content was determined by deducting ash content, protein, crude fibre, and lipid, from the total dry matter.

The energy value of the pulp waste samples was determined by utilizing the Atwater factors for crude protein, total carbohydrate, and crude lipid, as follows:

Energy value (E) [kcal·$(100\ g)^{-1}$)] = (crude protein × 4) + (total carbohydrate × 4) + (crude lipid × 9).

Determination of mineral element constitution. The mineral element evaluation was done to quantitatively analyze mineral distribution in the citrus pulp waste segments. Elements including copper, calcium, magnesium, iron, manganese, phosphorus, potassium, sodium, zinc, and nitrogen were analyzed using a inductively coupled plasma ICP-OES analyzer (Varian 710-ES Series, SMM).

Sample preparation and analysis of yellow maize. The yellow maize was crushed into fine particles using a blending machine and neatly packed into clean plastic bottles and labelled, then they were kept in cool conditions, before carrying out further analysis. The same procedure that was used for analysing the proximate and mineral contents for the *Citrus* pulp waste was also utilized for the yellow maize. All analysed samples both citrus pulp waste and maize were done in triplicate.

Data analysis. Raw data were subjected to a one-way analysis of variance (ANOVA) and mean separation by LSD test ($P \leq 0.05$), using Minitab 19 statistical package. There was homogeneity of variances of data from the plant species.

RESULTS

Proximate composition of whole *Citrus limon* and *Citrus x clementina* fruit, and maize. The nutritional analysis showed that the yellow maize had a significantly higher values for moisture content, carbohydrate, fibre and caloric value compared to citrus pulp waste from both farms. The lipid content value of yellow maize was comparable to the Eureka lemon pulp from farm 1, but significantly higher than the citrus pulp waste of the rest of samples. On the other hand, the protein content of the citrus pulps from both farms were significantly higher compared to the yellow maize (Table 1).

Mineral Composition of whole *Citrus limon* and *Citrus x clementina* fruit, and maize. Citrus pulp waste from both farms had significantly higher mineral components compared to the yellow maize, except for phosphorus (Table 2).

DISCUSSION

Moisture content has been pointed to be a vital index for the shelf-life duration of plants, with high moisture contents tending towards a lower shelf-life (Uyoh et al., 2013). The moisture content in *Citrus* pulp waste (Eureka lemon and Clementine) from both farms, and in the yellow maize (Table 1), was relatively low which is indicative of a potential long shelf-life and highly durable nature (Alagbe and Betty, 2019). The moisture levels of the samples in our study were in consonance with dried citrus pulp waste (3.5-13.7 %) reported in an earlier study by Alnaimy et al. (2017). However, the values were lower compared to the content in dried citrus pulps and orange pulps given by the National Research Council (NRC, 2001).

The ash content was appreciably high in all the citrus pulp waste from both farms, but lesser in the yellow maize (Table 1). The ash content values for all the samples were in line with the ones (3.1-8.4 %) reported by Alnaimy et al. (2017).

With regards to dietary fibre in plants, it is a vital component in feed because it aids the digestive system while reducing serum cholesterol levels in animals (Omokore and Alagbe, 2019). The fibre content in the yellow maize (Table 1) was somewhat comparable to the one in maize sample (26.15 %) reported by Ülger et al. (2020).

Likewise, the crude fibre of lemon pulp (11.52 %) reported by the same authors was comparable to the Clementine pulp waste from farm 1.

Table 1. Proximate composition (%) of *Citrus* pulp waste (lemon and Clementine) from two different farms as compared to yellow maize

Composition (%)	ELF1	ELF2	CF1	CF2	Maize
Moisture	4.02 bc	5.75 b	3.96 bc	3.49 c	9.22 a
Ash	6.44 a	5.75 a	6.23 a	4.99 c	1.47 d
Lipid (Fat)	4.09 a	1.49 d	3.49 b	1.90 c	4.13 a
Carbohydrate	1.51 b	2.12 b	ND	1.29 b	68.24 a
Protein	7.14 c	6.13 d	9.93 a	8.26 b	5.06 e
Fibre	27.07 ab	26.36 ab	12.97 b	17.40 ab	30.66 a
E [kcal·(100 g)$^{-1}$)]	71.37 b	46.47 c	71.09 b	55.34 bc	330.39 a

Values followed by different letters in each row are statistically different according to the LSD test ($P \leq 0.05$). E: Energy value; ELF1: Eureka Lemon, Farm 1; ELF2: Eureka Lemon, Farm 2; CF1: Clementine, Farm 1; CF2: Clementine, Farm 2. ND: Not determined

Furthermore, the crude fibre content in the Clementine pulp waste from farm 2 was in line with the 16.8 % reported by Alnaimy et al. (2017), but were lesser to the lemon pulp waste in both farms. The high content of crude fibre in the lemon pulp waste (26.36-27.07 %), although somewhat lesser compared to the ground yellow maize, is indicative of their potential as feed resource. According to Steyn et al. (2017) dried citrus pulp is a rich-fibre waste material/by-product and when used in total mixed ration (TMR) systems.

The protein content in the *Citrus* pulp waste (particularly Clementine) from both farms is commendable (Table 1), and this could make them useful protein supplements in diets. The protein content recorded in the current study for the *Citrus* pulp waste and yellow maize is higher compared to the flesh, peel and peel extracts of *Musa sinensis* (1.71 %, 2.48 % and 2.51 %) and *Musa paradisiaca* (1.22 %, 2.23 % and 1.82 %) that was reported by Oyeyinka and Afolayan (2019).

Furthermore, it was shown that the protein content from the *Citrus* pulp waste from the two different farms were within the range of 6.00-8.68 % for protein content from dried *Citrus* and orange pulps that has been earlier reported (Allam et al., 2020). However, protein content of yellow maize was significantly lower than all samples of *Citrus* pulp waste. Although, the crude protein values in the citrus pulp waste where appreciable, according to Alagbe et al. (2020) they would not be best suited as a protein supplement in animal feed. On the contrary, based on the study by Luzardo et al. (2021), fresh citrus pulp can have positive effect on animal dietary and performance.

The obtained carbohydrate values in the *Citrus* pulp waste (Table 1) were comparable to other recorded fruit and vegetable wastes such as courgette (1.99 %), cucumber (2.17 %), coriander (2.16 %), spinach (2.38 %) and tomatoes (2.93 %), as reported by Kamau et al. (2020). In our study yellow maize was shown to have a very high carbohydrate content, which was expected, since grains like maize are known to be the main energy source of nutrients in the diets of animals. The low level of carbohydrate contents in the citrus pulp waste implies that they may not serve as useful energy sources in diets as they may only be good as supplements to provide other important nutrients for animal utilization.

Conversely, high starch content in cereal grains has been fingered to have limiting effect on other physiological responses of the animal. Despite this known challenge associated with feeding high carbohydrate/starch contents, it is still practised widely due to the high energy content that they possess, which promotes good production performance (Steyn et al., 2017).

Dietary fats content in the citrus pulp waste from farm 2 was in accordance to the level (1.3 %) reported by Alnaimy et al. (2017), but it was less than the *Citrus* pulp waste in farm 1, and in the yellow maize (Table 1). Furthermore, the fat contents as recorded in the present study (citrus species and yellow maize) were higher compared to most fruit and vegetable waste such as courgette (0.25 %), cucumber (0.21 %), coriander

(0.09 %), spinach (0.17 %) and tomatoes (0.12 %), as reported by Kamau et al. (2020).

The fact that lipid content of the waste pulp varied between species and locations is in agreement with the findings of Wadhwa et al. (2013) who stated that the response is affected by environment and plant physiological factors, including plant species. In the present study, it could be attributed to the different climatic conditions between farms 1 and 2, and the different genetic expressions between Eureka lemon and Clementine.

Table 2. Mineral composition of citrus pulp waste (lemon and Clementine) from two different farms as compared to yellow maize.

Minerals [mg·(100 g)$^{-1}$)]	ELF1	ELF2	CF1	CF2	Maize
Calcium	290.00 b	240.00 c	210.00 d	346.67 a	10.00 e
Magnesium	126.67 b	120.00 b	146.67 a	140.00 a	100.00 c
Potassium	1713.33 b	1613.33 c	1793.33 a	1443.33 d	350.00 e
Sodium	60.00 a	43.33 b	56.67 ab	46.67 ab	20.00 c
Phosphorus	140.00 d	166.67 c	240.00 b	180.00 b	233.33 a
Zinc	262.00 b	254.77 b	277.90 a	106.37 c	0.65 d
Manganese	1.47 a	0.90 b	0.93 b	1.00 b	0.50 c
Copper	0.87 a	0.43 bc	0.37 b	0.50 b	0.00 d
Iron	45.77 a	35.57 b	30.23 d	18.97 d	2.90 e
Na^+/K^+	0.03±0.002	0.02±0.001	0.03±0.004	0.03±0.009	0.06±0.002

Values followed by different letters in each row are statistically different according to the LSD test ($P \leq 0.05$). E: Energy value; ELF1: Eureka Lemon, Farm 1; ELF2: Eureka Lemon, Farm 2; CF1: Clementine, Farm 1; CF2: Clementine, Farm 2

The mean value for energy content of each of the components of the *Citrus* pulp waste was relatively low (Table 1), but it was high in the yellow maize (330.39 %), which was expected, since it is an energy feed ingredient. The low carbohydrate, moderate lipid and protein levels were pronounced in the derivative energy contents in this study. Energy value for the citrus pulp waste samples was comparable with a study of fruits and vegetable wastes which ranged from 3.06 to 40.00 kcal·(100 g)$^{-1}$) (Kamau et al., 2020).

The mineral content showed that citrus pulp waste (lemon and Clementine) from the two farms had significantly higher concentration compared to the yellow maize, except for phosphorus (Table 2). However, all mineral content values were within the ones recommended by the World Health Organization guidelines (WHO, 1991).

Calcium value in the *Citrus* pulp waste were higher than those recorded for yellow maize (Table 2). The reported values of calcium content given by the NRC (2001) for animal feed composition ranged between 1840 and 1920 mg·(100 g)$^{-1}$. However, the calcium content in the citrus pulp waste from the present study were lower compared to the values of the NRC, and the 1600 mg·(100 g)$^{-1}$ reported in earlier study by Bampidis and Robinson (2006). The reason for this observation may not be clearly understood, but may be as a result of different region of study, stage of harvest of citrus species and the method of processing of the citrus species.

Magnesium content was reasonably quantifiable in the citrus pulp waste from both farms, apart from yellow maize that was slightly low (Table 2). Magnesium levels in the citrus pulp waste and yellow maize were moderate in quantity, just as ADAS (1992) and Bath et al. (1980) observed in dried citrus pulps in their studies.

The reported values of potassium content given by the NRC (2001) for livestock feed composition ranged between 620 and 1100 mg·(100 g)$^{-1}$. Potassium content was significantly higher in citrus pulp waste when compared to the yellow maize (Table 2). The values of the potassium content in the citrus pulp waste from both farms were also higher compared to the citrus pulp values of 820 mg·(100 g)$^{-1}$ reported by Bampidis and Robinson (2006) and those of 680-1160 mg·(100 g)$^{-1}$ reported by ADAS (1992).

Sodium content was relatively low in the citrus pulp waste and in yellow maize (Table 2) when compared to the value 100 mg·(100 g)$^{-1}$ reported for citrus pulps in the study by Ensminger and Olentine (1978). However, the value for the

sodium content in the present study for citrus pulp waste from the two farms were higher compared to the value of the dried orange pulps of 30 mg·(100 g)$^{-1}$ compiled from the results of a previous study (Bampidis and Robinson, 2006). The elemental and chemical constituent of citrus pulps is known to be influenced by various environment and plant physiological factors (Wadhwa et al., 2013). In our study, this could be related to the different climatic conditions of both farms, and may perhaps be the reason for the observed variation in the result of sodium content.

Sustaining the ionic balance/equilibrium in feeds obliges the use of K and Na in diets. From the present study, high to low mean value of potassium to sodium content is responsible for the recorded low Na^+/K^+ ratio (Table 2). This observed low ratio is vital because it gives an ideal Na+/K+ that will support the balance of ions in feed.

The phosphorus content in the yellow maize was significantly higher compared to those in the citrus pulp waste (Table 2). The reported value by the NRC (2001) for phosphorus content in livestock feed ranges between 110 and 120 mg·(100 g)$^{-1}$ for dried citrus pulp, dried orange pulp, and citrus pulp silage, which is similar to our findings. On the contrary, the yellow maize in the present study had higher phosphorus content than that of NRC. In addition, the result for the phosphorus content in citrus pulp waste in the present study is in line with the value 110-150 mg·(100 g)$^{-1}$ compiled from the results of several previous studies (Bampidis and Robinson, 2006; Alnaimy et al., 2017).

The value for zinc content in citrus pulps given by the NRC (2001) ranges from 1100 to 1600 mg·(100 g)$^{-1}$. This means that the value for zinc content in the citrus pulp species and yellow maize in the present study was quite low (Table 2).

The recorded value for manganese content in livestock feed ranges 0.7-0.9 mg·(100 g)$^{-1}$ for dried citrus pulp and orange pulp (NRC, 2001) is comparable to the value obtained in the lemon pulp waste from farm 2 (Table 2). In addition, the value for citrus pulp waste (lemon from farm 1 and Clementine from farm 1 and 2) was in line with the values of 0.5-1.4 mg·(100 g)$^{-1}$ reported by ADAS (1992). The values for manganese were higher compared to yellow maize, and show that they can be a good supplementary source of manganese in feedstuff.

The copper content for citrus pulps were in consonance with the range of 0.3-0.6 mg·(100 g)$^{-1}$ reported by ADAS (1992), except for the lemon pulp waste from farm 1 (Table 2). Meanwhile, our findings showed copper contents that were somewhat above or below the range of 0.6-0.8 mg·(100 g)$^{-1}$ reported by the NRC (2001). On the other hand, there was no detection for copper content in yellow maize as seen in Table 2. The low copper content reported for the lemon pulp waste from farm 2 and Clementine pulp waste from both farms may be commendable since they are required in low amount by the livestock.

The iron content in the lemon pulp waste from farm 2 and Clementine pulp waste from 1 and 2 (Table 2) were within the range 15.1-37.7 mg·(100 g)$^{-1}$ recommended for livestock feed by the NRC (2001), but the iron content value recorded for lemon pulp waste in farm 1 was above that range. On the other hand, iron content was quite low and below the NRC threshold in yellow maize.

CONCLUSIONS

The study revealed that the citrus pulp waste from Eureka lemon and Clementine contain comparable amounts of fibre when compared to yellow maize, but with significantly higher protein contents. More visibly is the fact that these citrus pulp wastes were especially rich in several nutrients including Ca, Mg, K, Na, Zn, Cu, Mn and Fe, except for phosphorus, when compared to yellow maize and should therefore be considered as a rich naturally available nutrient for animal feed. The study also revealed the potentials of citrus pulp waste to be put to more relevant livestock nutritional use. Since citrus pulp waste are relatively free of charge raw materials that is widely available in South Africa (although seasonal), its feeding value should be fully investigated with the common farm animal species in the region both by local and commercial farmers.

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