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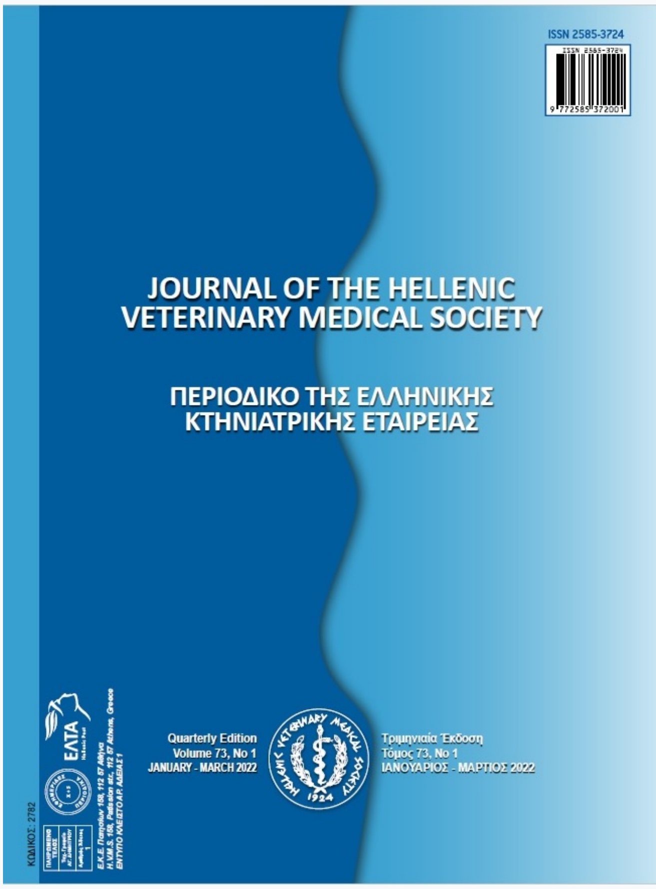

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Nutritional evaluation of the agro-industrial by-products and waste fruits - vegetable for sustainable ruminant nutrition

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ABSTRACT: The growing consumption of ruminant animal products gives rise to a huge demand of animal feed in growing countries.By-product feeds, waste fruits-vegetables, and crop residues should be considered as a valuable alternative feed resource in ruminant nutrition. This wastecan be reutilized and converted by ruminants to valuable products for human benefits as a new resource and in return to increase the effectiveness of limited feed sources. But, there are limited new information and research regarding the nutritive value of this waste for ruminants. For this purpose, the experiment was conducted to evaluate the nutritional potential of some agro-industrial by-products, waste fruits-vegetable, and crop residue for ruminants specifically. Fourteen by-products, waste fruits-vegetable and crop residue were collected from the west part regions of Turkey. Nineby-product feeds (whole cottonseed, rice bran, soybean hull, apple pomade, citrus pulp, grape pomade, tomato pomade, grape stalk, rice hull), three waste fruits (dry grape, dry fig, carrot), one waste vegetable (potato) and also one crop residue (cornstalk) were analyzed for nutritional composition and metabolizable energy values were calculated by crude nutrients for ruminants. Further, energy, DMD, and OMD of these samples were investigated by using the cellulose enzyme method. All samples were analyzed the macro minerals (Ca, P, Na, K, and Mg) and the microelements (Fe, Cu, Mn, and Zn) contents. In the research, all samples regarding the parameters in DM, ash, OM, CP, EE, CF, NFE, NSC, NDF, ADF, starch, sugar, Ca, P, Na, K, Mg, Fe, Cu, Mn, Zn, DMD, OMD, ME_{CN}, and ME_{CEL}were different ($P<0.05$). Thestudy showed that the waste fruits, vegetable, and by-products have valuable sugar (grape, fig, and carrot), starch (potato, rice bran), NSC (citrus pulp), and oil (cottonseed) content that is the main compounds making them high energetic feeds for ruminants. Also, most of these research materials have enough or much more macro and micro mineral concentrations for ruminant nutrition.

***Keywords*:** By-products, Fruit, Vegetable, Ruminant

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INTRODUCTION

The growing world population depends on the consumption and use of limited and diminishing natural resources such as arable land, fuel oil, fertilizer, and water. However, the enlargement of human urbanization and with them increase of agricultural production has caused not only environmental adversities such as climate change, soil, and water degradation but also economic and social concussion (Anguloa et al. 2012). The increased demand for plant and animal foods needed to meet the basic nutritional needs of people while making the already existing pressure on agricultural production even more noticeable (Dou et al. 2016). Also, the prediction byFAO (2011) that the human population will reach 9.5 billion and the world would need 73 percent more meat and 58 percent more milk in 2050 (Wadhwa and Bakshi 2013). Especially in animal production, to meet high feed requirement demands, a huge quantity of feed resources supply and the sustainability of the feed production systems must be considered carefully.Also, there is already a considerable scarcity of feed accessibility in most developing and developed countries for animal production (Godfray et al. 2010).

Therefore, it is necessary to use the limited resources most efficiently and to evaluate the foods obtained as the least waste, while raising the interest in alternative feed materials that can increase the productivity by animal species and reduce the food competition between animals and humans. Considering that approximately 30% of food produced (1.3 billion metric tons) is waste before reaching people (Ajila et al. 2012), and also each day the matters riseas long as the amount of waste produced is greater than the amount of waste.Therefore, serious attention to waste management is essential for sustainable animal production.

Several factors have led to increased interest in by-product feeds and waste foods such as pollution abatement, regulations, increasing cost of waste disposal, and changes in perception of the value of these feed as economic feed alternatives (Belyea et al. 1989). The primary reason for using by-product feeds and waste foods as feed material is to reduce feed cost and also during a drought or when is high fiber forages limited. By-product feeds come from various agro-industrial sources including such as grain processing, extraction of juice processing industry, brewing- wine distillery industry, marketplace or bazaars that are main sources of fruit and vegetable wastes, or crop harvesting, etc. Although many of these feeds have been used for years, others like fruit and vegetable wastes as ruminant feed are relatively new (Bernard 2010; Anguloa et al. 2012). Agricultural and industrial by-products are generally cellulosic in nature, with a high cellulose and hemicellulose content and less efficient to the animal except for ruminants (Agus, 2015; Bernard 2010). Ruminants have a valuable role in sustainable animal production and their rumen serves as a fermentation tank containing the microbial cellulose enzyme that is the only enzyme to digest the fiber fractions rich in the by-products feed stuffs, Oltjen and Beckett (1996).

Livestock is one of the fastest-growing agricultural sectors in developing countries. Also, the demand for animaloriginated foods is rapidly increasing in most developing countries.However, many developing countries have feed deficits. New unconventional alternative feed resources such as agricultural and agro-industrial by-product feeds, fruits, vegetables, and crop residues originated feeds could play an important role in meeting this deficit, Wadhwa and Bakshi (2013). Besides, their use in the ruminant ration can also reduce the cost of feeding, giving higher economic advantages to producers. These by-products feeds, which contain little economic value as foods for human consumption would become considerable sources of dietary nutrients and energy in ruminant nutrition. Their use can also reduce the cost of feeding, giving higher profits to producers. These by-products feeds, which contain little economic value as foods for human consumption would become considerable sources of dietary nutrients and energy in ruminant nutrition.However, there has been little new research regarding the nutritional value of the agricultural and industrial by-products feedstuffs in ruminant nutrition. The aim of this study was to know and reevaluate the nutritional value of some agro and agro-industrial by-products feeds for ruminant nutrition.

MATERIALS AND METHODS

Sample collection

Nine different types of by-product feed; apple pomace, citrus pulp, grape pomace, grape stalks, tomato pomace, cottonseed, rice bran, rice hull, soybean hull; three fruits; carrot, dry fig, dry grape; one vegetable; potato and one crop residue; corn stalk were provided by six different agro-industrial factories, bazaars and harvested corn fields for nutritive evaluation based on their use in ruminant nutritionin Izmir/Turkey. Each by-product, vegetable, fruits, and crop residue consists of six different samples; each one is analyzed in three replicates one by one for each parameter. Before chemical analyses, all experimental samples were ground through a 1 mm screen in preparation for chemical analysis and stored at 4°C in a refrigerator until analysis.

Nutrient composition

Nutrient contents of air-dry samples were analyzed according to the methods reported in AOAC (1997), and all data were presented on a dry matter basis. All samples were analyzed for dry matter (DM) (method 934.01), ash (method 942.05), crude protein (CP) (method 990.03), ether extract (EE) (method 920.39), crude fiber (CF) (method 962.09). The sugar content of the materials was determined by the Luff-Scroll method and the starch determination by the polarimetric method, AOAC (1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were determined using the methods by Van Soest et al. (1991). Nitrogen-free extracts (NFE) were calculated as 100-% (moisture+CP+EE+CF+ash). Non-structural carbohydrate content (NSC) was obtained using the following equations as 100-% (NDF+CP+EE+ash). Organic matter (OM) was calculated as OM%=DM%-ash%.

Phosphorus (P) contents of the materials were read by spectrophotometer (model PE General TU-1880 Model Double Beam UV-V15) by calorimetric methods. Atomic absorption spectroscopy (Ultrospec2100 pro UV/visible 106 spectrophotometer) was used for determining calcium (Ca), potassium (K), sodium (Na), magnesium (Mg), iron (Fe), copper (Cu), manganese (Mn), zinc (Zn) concentrations.

Estimates for crude nutrition metabolizable energy (ME_{CN}) as kcal kg^{-1} in DM were based on crude nutrients (protein, fiber, and fat levels) determined from the samples using a prediction equation, TSI-9610 (1991) ;

ME_{CN}kcal kg^{-1}:3260+ (0.455xCP+3.517xEE-4.037xCF) and CP, EE, CF quantities in OM (gkg^{-1}).

All nutritional parameters, mineral contents, and energy values of the samples are given on a dry matter basis.

In vitro digestibility

The in vitro dry matter digestibility (DMD), organic matter digestibility (OMD), and *in vitro* cellulose enzyme metabolizable energy (ME_{CEL}) were determined according to the cellulose enzyme method described by (De Boever et al. 1986) modified from Tilley and Terry (1963). The in vitro OMD was estimated by the equation developed by Weissbach et al. (1999). The enzymatic procedure investigated comprises 3 steps: (1) pepsin (Sigma) in 0.1 M HCl at 40°C for 24 h; (2) starch hydrolysis in the same solution at 80°C for 45 min; (3) cellulase (from *Trichodermavir-ide, Serva*) at 40°C for 24 h. The *in vitro* digestibility analyzes were serially performed on each sample in triplicate. Values are expressed on a dry matter basis in all equations. Enzymatic DMD, OMD, and *in vitro* ME_{CEL} were calculated using the following equations;

DMD, %= IVDMD %: $((A_n - (A_k - A_o)) / A_n) \times 100$

OMD, %=IVDOM %:100 x (940-CA-0.62 x EULOS-0.000221 x $EULOS^2$) / (1000-CA)

ME_{CEL} (Mcalkg^{-1}DM) = (1.04 + (0.00001611 x $ELOS^2$) + (0.3724 x EE) - (0.0003674 x ELOS x EE) - (0.0004919 x EE x CF) + (0.01548 x CF)) /4.186

*EULOS; enzyme insoluble OM, A_n; sample weight (g), A_o; crucible tare (g), ash%and EULOS in (g) DM

Statistical analysis

The statistical analysis of the results included a one-way analysis of variance ANOVA using General Linear Models and Duncan's multiple range test, which were applied to the results using the IBM SPSS Statistics 25, SPSS (2016). The model included by-product feed samples as main effects. Differences were considered to be significant based on the 0.05 level of probability.

RESULTS

The means and standard errors for the nutrient composition and mineral content of fourteensamples are given in Table 1 and Table 2 respectively. Also, Table 3 showed the DMD, OMD, ME_{CN}, and ME_{CEL} values of the samples.

The differences among the by-product feed (apple pomace, citrus pulp, grape pomace, grape stalk, tomato pomace, whole cottonseed, rice bran, rice hull, soybean hull) fruits, (carrot, fig, grape), vegetable (potato), and one crop residue (corn stalk) in DM, ash, OM, EE, CP, CF, NFE, NSC, NDF, ADF, starch, and sugar contents were significantly different $P<0.05$. The DM content of the by-product feedswas within the range from117 to 935 g. In terms of the DMcontent of the by-product feeds had a great variation. Carrot had the lowest DM content, while corn stalk had the highest DM content. The overall average means of the ashes in by-product feeds varied between 24 and 193g. The rice hull had extremely high ash content compared with other by-product feed samples. The average OM content of samples was quite high (806-975g). Rice hull and rice bran, in samples, were lower the OM content other than.The EE content of by-product feeds and other samples were considerably variable; cottonseed, rice bran, tomato pomace, and grape pomace had the highest EE content (177.7, 159.8, 84.5, and 75.7g respectively).On the other hand; potato and rice hull had the lowest average EE content (3.3 and 5.3 g respectively) among the samples. Concerning to the protein average means, in the by-product samples ranged from 219.6g to 61.2g. When samples are compared with each other; cottonseed, and tomato pomace were higher CP content (219.6 and 196.3 g respectively) while corn stalk and fig were lower CP (61.2 and 66.1 g respectively) content.

The NFE values calculated for research samplesranged the lowest in tomato pomace and whole cotton seed 206.4 and 224.9 g to the highest in fig and potato both the same value 783.9 g.Similarly, NSC means as NFE were the lowest in rice hull, cottonseed, and tomato pomace (16.2, 32.1, and 56.3g) on the other hand; fig, carrot, and potatohad the highest NSC values (731.0, 683.2 and 660.3 g) in the samples.

In the study, the CF content of the by-product feeds had a great variation. The cellulose concentration of the by-product feedswas within the range from 119.4 to 506.2 g. When rice hull, tomato pomace, and soybean hull had the highest CF contents (506.2, 454.2 and 411.7 g respectively), potato, and fig had the lowest average fiber concentration (19.4 and 76.6 g respectively). Except for some fruits and vegetables such as fig, potato, and carrot (129.6, 143.0, and 143.8g) were lower NDF content than all the other by-products feeds and research samples. Cornstalk and rice hull showed the highest NDF concentrations (766.0 and 745.4g respectively). The ADF showed that the potato had a lower mean value (22.1 g) than other by-product feeds means. The highest ADF content was seen in rice hull as 645.3 g.

When the starch content was not determined in grape, fig, carrot, and corn stalk; also rice hull and grape pomace had the lowestmean and both the same value (12.7 g), and potato had the highest starch content (642.0 g) among the samples. The sugar content ranged from 5.9g to 235.1g in by-products feed, fruits, vegetable, and crop residue samples; with the lowest content, in rice hull, tomato pomace, and cottonseed (5.9, 17.2, and 19.7g respectively) and highest value recorded for fig and carrot (235.1 and 235.0 g respectively).

The means and standard errors for the mineral content of by-products feed, fruits, vegetable, and crop residue (apple pomace, citrus pulp, grape pomace, grape stalk, tomato pomace, cottonseed, rice bran, rice hull, soybean hull, carrot, fig, grape, potato, corn stalk) were given in Table 2. All the observed parameters related to mineral contents as Ca, P, K, Na, Mg, Fe, Cu, Mn, and Zn of the feed samples were found significantly different $P<0.05$. When the citrus pulp and grape stalk had the greatest concentration of Ca (17.3and 15.9 g respectively) ; rice bran and potato had the lowest concentrations of Ca (1.4 and 1.9g respectively) compared with all the other feed samples.

The mean P content was the highest in rice bran (6.6g) and the lowest in rice hull (0.1g). The phosphorus concentration was less than 1% in all samples. The potassium means the value of the by-product feedswere within the range from 6.9 to 24.9 g. The K concentration in rice hull and apple pomace (6.9 and 8.6g) is the lowest and significantly lower than all other by-product feeds. Except for the rice bran (8.4g), all the other samples were less than 5.9g mean values for the Mg content. When the Na content was the highest for carrot (5.3g), the lowest for the citrus pulp and corn stalk samples (both the same value 0.5g). The Fe content was the highest for corn stalk, soybean hull, and grape (619, 509, and 372mg), the lowest the fig (141mg). The Mn content was greater than the grape stalk (133 mg) compared with the other by-product feed samples. The Cu concentration was the lowest for the corn stalk, rice bran, fig, and apple pomace (54, 56, 57, and 57 mg) and the other samples ranged 59 to 80mg.The Zn content in terms of micro minerals for research samples ranged from 8.8 to 26.1mg. The Znconcentration mean value was the highest for rice hull (26.1 mg), the lowest for the citrus pulp (8.8mg).

The values of *in vitro* DMD, OMD, ME_{CN}, and ME_{CEL} contents of by-products feed, fruits, vegetables, and crop residue samples are shown in Table 3; and all parameters were observed significantly differences $P<0.05$. In terms of DMD, considerable variation was observed among the samples. The DMD values were obtained in all samples (ranged 10.3 to 96.0%).The

DMD was the highest for citrus pulp and potato (96.0 and 95.8% respectively), the lowest for the rice hull (10.3%). The OMD of the samples were ranged from 22.8% for the rice hull to 95.7% for potato average value. In the study, OMD values of the samples were seen similar to DMD means. The average ME_{CN} value in by-products feed, fruits, vegetable, and crop residue samples was the highest for rice bran and potato (3118 and 3052 kcal/kg) and the lowest for rice hull (640kcal/kg) average mean. The ME_{CEL} value was ranked 723 kcal/kg (rice hull) to 3310 kcal/kg (rice bran).

DISCUSSION

The present study was performed to evaluate the nutrition value of the by-product feeds (apple pomace, citrus pulp, grape pomace, grape stalk, tomato pomace, cottonseed, rice bran, rice hull, soybean hull) fruits, (carrot, fig, grape), vegetable (potato), and one crop residue (corn stalk) for ruminant nutrition. When samples were grouped in four classes (by-products, fruits, vegetables, and crop residue), DM was the lowestin carrotand potato compared with other samples. All by-products and other feed materials showed considerable variation within the DM contents. Findings the DM determined in this study are consistent with the findings of relevant studies (White 1985; Arosemena et al. 1995; Aghsaghali and Sis 2008; Lardy and Anderson 2009; Azevêdo et al. 2012; Eliyahu et al. 2015; Wadhwa et al. 2015). However, the range reported by Gupta et al. (1993) (carrot, potato) and INRA (2004) (rice bran, soybean hull, cottonseed) were lower, when DM contents declared by NRC (2001) (apple pomace, tomato pomace) ; and Filleau et al. (2018) (apple pomace, grape stalk) were exceptionally high value some samples.These differences could be due to different agronomic practices adapted in different regions and also originated by different industrial processing methods. (Lardy and Anderson 2009) indicated that water content may result in excessive effluent losses and reduce ration dry matter content.Also the high DM or low moisture content in ruminant nutrition is very important because of providing easy storage and use for ration. Meanwhile, the high moisture content in by-products and food waste can cause difficulties in balancing ration dry matter content, storageand also increase microbial growth (Kabak et al. 2006; Tretola et al. 2017). When using these types of feed that have low dry matter content such as vegetables, fruits or by-products may have to be used as soon as possible and using together with dry forages to balance the dry matter content of the TMR.

Our finding ofthe ashand calculated OM content of the study samples were found similar with results of relevant studies in general (White 1985; Arosemena et al. 1995; NRC 2001; INRA 2004; Azevêdo et al. 2012; Wadhwa et al. 2015). Except for the rice hull (193g), other samples had a low quantity of the ash contents that were ranged from 24 to 88 g. Although the rice husk has high ash content, it consists of approximately 90% silica while the useful mineral concentration is lowWhite (1985). On the other hand; the low ash and high OM contents of them suggest that they may be valuable feed resources in ruminant nutrition.

The findings about EE content of research samples are consistent with the findings of relevant studies (Arosemena et al. 1995; NRC 2001; INRA 2004; Azevêdo et al. 2012; Wadhwa et al. 2015) but it is lower than the value found by (Kajikawa 1995).In the experiment, cottonseed and rice bran had the greatest concentration of EE compared with all the other selected feed samples.These by-products could be used successfully as a source of energy, protein, and fiber in ruminant ration (Wadhwa and Bakshi 2013). Since the whole cottonseed has high fat and protein contents, it may be defined as a concentrate feed Arieli (1998). Although the high oil content of the cotton seed (about 20% of dry matter) has a suppressive effect on rumen microbial activity, it should be considered as a good energy source for ruminants.

In terms of the CP content by-product feeds, fruits, and vegetable showed the low mean value and variability, except with cottonseed and tomato pomace. The findings about CP contents of experiment samples are consistent with the findings of the relevant studies in general (Kajikawa 1995; NRC 2001; INRA2004; Wadhwa et al. 2015; Filleau et al. 2018). However, some researchers have reported that higher CP content (Belyea et al. 1989; Azevêdo et al. 2012). Based on this study data, the average CP contents of the samples could vary 39.0 from to 219.6 g.The differences in protein content may vary depending on the origin of the by-products, food industrial production process, or used different agronomic production model.The results related to the CP contents suggest that the by-products, fruits, vegetables and crop residue should not be considered as a good source of protein because of the low concentration and origin (Azevêdo et al. 2012; Wadhwa et al. 2015) except the cottonseed and tomato pomadefor ruminant. However, Arieli (1998) concluded that the protein in the cottonseed has high rumen degradability of about 70-77%

and can be use a good protein source in the ruminant ration. Results of NFE and NSC contents agree with findings of NRC 2001; Bernard 2010; Wadhwa et al. 2015. The NFE and NSC concentrations of the potato, fig, grape, carrot, and citrus pulp were similar and these samples had higher mean value than others in the study. On the other hand, the research showed that the tomato pomace, cottonseed, and rice hull had lower contents both of NFE and NSC in accordance previously mentioned by Bernard (2010).

As expected in the study, there was no starch in the fruits (grape, fig, and carrot) and corn stalks, but a very low starch content was found in other by-product feed samples except the potato (642.0 g). These findings agree with the previously reported study results or data by Belyea et al. 1989; Kajikawa 1995; INRA 2004; Filleau et al. 2018. As a result, the potato had a very high starch concentration feeding value equal to cereal grain such as barley or corn grain on a dry matter basis, INRA (2004). Satisfactory results can be obtained in finishing or dairy cattle rations by feeding potatoes as energy source raw feed material like cereals (Nelson et al. 2000; Lardly and Anderson 2009). On the other hand, the research showed that fruits (grape, fig, and carrot) and citrus pulp had higher sugar content than all others. Most of the research or literature has focused on the starch concentration of feed samples, while limited information is available on sugar content.This study showed that sugars constitute an important part of carbohydrates in the fruits samples. As known, carbohydrates are especially starch and fiber as primary nutrition components that contribute up to 70% of the diets, used to dairy cows and beef steers (Allen 1996). Also, sugars may be good alternative energy sources for any adverse effect on rumen fermentation and animal performance. Generally, sugars are known as water-soluble carbohydrates that are readily available in the rumen, and consist of disaccharides, such as sucrose, lactose, and maltose, and monosaccharaides, such as glucose, galactose, and fructose (Oba 2011). Thus, feeding sugar or when sugar replaced dietary starch, improves rumen degradable protein utilization (Broderick 2008) dry matter intake and milk fat content. The fruits waste (grape, fig, carrot), potato, and by-products (citrus pulp) having high sugars, starch, and pectin content, could form a significant part of ruminant ration as energy resource on dry matter basis.

Based on the structural carbohydrate contents such as NDF, ADF, and CF contents of the by-products and other research samples, were significantly different from each other. Waste fruits and vegetable had low NDF, ADF, and CF contents, because these samples were composed primarily of simple or water-soluble sugar or pectin (Wadhwa et al. 2015). This funding agrees with previously reported research that by-product samples characterized by comparable fiber (Kajikawa 1995; NRC 2001; INRA 2004; Wadhwa et al. 2015; Filleau et al. 2018). Fiber is the main carbohydrate fraction of ruminant rations and is necessary to provide adequate amounts of complex carbohydrates to slow digestibility and control the acidity in the rumen for healthy rumen fermentation. Because dairy or beef steers require fibrous feedstuffs in the diet, the ADF and NDF content of the feeds are important fiber fractions that need to be carefully considered in balancing the ration formulation (Varga et al. 1998). Utilizing this kind of waste fruits, vegetables, and by-products for ruminant feeding, ADF and NDF contents should be carefully considered in ration making. Cornstalk and rice hull can be used as straw because of nutrition contents are similar to other cereal residues such as straw.

Considering DMD and OMD values of the research samples have shown considerable variation. The potato, citrus pulp, carrot, and fig had higher digestion values than the other samples. These results compare with previously reported by Azevêdo et al. (2012) and Wadhwa et al. (2015) that fruit waste and vegetables are highly digestible depending on the origin or the mixture used in their preparation. Also, the small variations observed between research and lower digestion rate (DMD and OMD) for the rice hull, grape stalk, and grape pomade which are thought to be due to nutrition composition, especially structural carbohydrate contents (both NDF and ADF) and nonstructural carbohydrate level Wadhwa et al. (2015). So, both the high NDF-ADF and the low nonstructural carbohydrate content significant decrease in the DMD and OMD values of these samples may be interpreted as structural carbohydrate negatively affects the digestion of the feeds comparing with ruminant. On the other hand, fruits and vegetables having higher DMD and OMD values may be seen as related to having high nonstructural carbohydrate fractions.In the study, the reason why rice husk has the lowest DMD and OMD may be thought to be due to its high ash concentration, and this situation also supports the high negative correlation between ash content and digestibility. Also, there may be thought that the DMD and OMD digestibility of the samples had a negative strong correlation with their structural carbohydrate content (NDF and ADF or CF), and a strong positive correlation with their non-structural carbohydrate content (NFE and NSC).Although soybean has low NSC and high NDF content, its DM and OM digestibility is high. This may be explained by the fact that most of the structural carbohydrate content of the soybean hull consists of highly digestible pectin. Regarding the digestibility results of soybean hull (DMD 81.1% and OMD 79.1%) in this study confirm the mentioned by Bach et al. (1999) that because of high NDF digestibility of soybean hull can be used as a substitute for cereal bran in the concentrated feed fraction of the ration. Taken together, the nutrition composition and energy contents (ME_{CN} and ME_{CEL}) of the by-product feeds, fruits, vegetable, and crop residue were in line with the literature which declared that the content and amount of structural carbohydrates and also the type of non-fiber carbohydrate contents of a feed highly affectits digestibility (McDonald et al. 2012).

Data for concentrations of ME and have indicated that potato, rice bran, and fruits (carrot, fig, and grape) samples contained more ME_{CN} and ME_{CEL} than others, which may be a result of the high concentration of starch, sugar, and oil; and also low content fiber fractions in the by-product (NRC 2001; Wadhwa et al. 2015; Liu et al. 2018).The metabolizable energy values obtained by the calculation systems based on the chemical composition of feeds cannot accurately determine the true energy values, so an *in vitro* energy assessment was performed enzymatically and the experiment samples were similar or even slightly higher than the energy values found by the calculation.ME_{CN} and ME_{CEL} values are consistent with the results of NRC 2001, INRA 2004, and McDonald et al. 2012. As a study result, the rice bran, potato, fig, grape, and carrot had higher energy levels both of them (ME_{CN} and ME_{CEL}) as concentrated feeds on a dry matter basis. Interestingly, the grape pomace and grape stalk were seen haveto low DMD and OMD digestibility, but relatively higher energy values (both ME_{CN} and ME_{CEL}) compared to other samples.This situation can be explained as follows; because of the correlation between the energy values and nutrient contents of feeds, energy values of the samples decrease as the cellulosic or fibrous contents (NDF) increase; non-structural carbohydrate content (sugar or starch) increases as they rise (Weiss 1993). Also, Nicolini et al. (1993) decelerated that winery waste such as grape pomace and grape stalks, as a result of a decrease in lignin through the fungal treatment, the cellulose is better accessible to rumen micro flora and its DM digestibility is similar to forages.

The Ca concentrations of the research samples were observed a little variation in this study, and were similar to previously reported values (Macgregor 2000; NRC 2001; INRA 2004; Wadhwa et al. 2015). The citrus pulp and grape stalks had the highest Ca content than other samples. The contents of P in the by-product feeds, fruits, vegetable and crop residue observed in this study were within the range of previously published values (Macgregor 2000; INRA 2004; Wadhwa et al. 2015). Except for the rice bran and the potato, which contains an insufficient amount (1.4 and 1.9 g respectively) of Ca, all other research samples contained a higherquantity of Ca than the advisedrange for ruminants (0.40-0.80%, NRC 2001; 0.22-0.44%, NRC 1985). Contrary, in the study, the fruits (grapeand fig), by-products (soybean hull, apple pomace, citrus pulp, corn stalks, grape stalks, and rice hull) contained lower levels of P than recommended for dairy cattle (<0.22%, NRC 2001), while the remainder only had sufficient amount of P, exceptrice bran and cotton seed (6.6 and 4.6 g respectively). The dietary Caand P mineral metabolism in ruminant nutrition is closely related to each other. Their absorption and utilization in the animal body depend on the relative proportion (general calcium to phosphorus ratio, 2:1in diet) of the two minerals in the ration. Also, the Ca to P ratio on the absorption of calcium and phosphorus is a wide ratio that is not critical (unless Ca:P ratio of >7:1 or ≤ 1:1). Because this is considered acceptable in dairy cattle ration (NRC 2001). In the present study, the calcium to phosphorus ratio in all research samples wasenough large, except for potato, rice bran, and cottonseed. Thus, the concentrations of K, Mg, and Na relating to samples in the research were in line with the literature decelerated by Arosemena et al. 1995; NRC (2001), and INRA (2004). The corn stalks, citrus pulp, potato, rice bran, apple pomace, cottonseed, and grape pomace were deficient in Na (<0.16%, NRC 2001). In the research, the by-product feeds, fruits, vegetable, and crop residue samples contained a high amount of K, except the rice hull and the apple pomace, which were adequate to reference (<0.38%, NRC 2001) in K. Besides, in ruminants fed rations with high roughage content, this mineral deficiency is not observed, since the roughages contain high levels of potassium. In the research, because the potato, corn stalks and some b-products feeds (cottonseed, apple pomace, citrus pulp, and grape pomace) had a high Ca:P ratio and the lower content of Na; ruminants eating a relatively large amount of these feeds would need to supply additional P and Na resources to deal with their possible deficiencies. The Mg concentrations of all study samples contained adequate or high quantity of Mg which from the minimum requirement level for dairy cattle by (<0.03%, NRC 2001).

The concentration of the Fe, Cu, Mn, and Zn investigated as micro minerals for samples in this study were close or similar to what is expected in the previous literature byNRC (2001), INRA (2004), and Soni et al. (2014). Among the micro mineral contents of research samples, the contents of Cu wasenough high (<11 mg, NRC 2001) in all study samples. The Zn mean values of the experiment samples in the trial are quite lowreferred to (<40 mg, NRC 2001). All experiment samples contained greater amounts of Fe concentration (>50 mg) than required for ruminants. Similarly, research samples had higher quantities of Mn (>40 mg, NRC 2001), apart fromthe whole cottonseed. These results show that all the by-product feeds, fruits, vegetables, and crop residue samples were rich in many macro-micro minerals.Overall, these by-products, fruits, vegetables, or crop residue to supply to ruminant ration adequate amount of a lot of minerals, except Mg, Fe, Cu, Mn. In general, taking into account the biological functions of minerals such as animal health, reproduction, and growth, rations should be supplemented with deficient minerals to avoid loss of production.

CONCLUSION

The increasing global food and feed require finding alternative energy sources, which has led to researches in the field of non-conventional feed materials as by-product feeds, waste fruits-vegetables, and crop residues. Therefore, based on this research results regarding the nutrition composition of some waste foods and by-product feed indicates that (i) the waste fruits, vegetable and by-products have valuable sugar (grape, fig, and carrot), starch (potato, rice bran), pectin (citrus and pulp) and oil (cottonseed) content that are the main compounds making them high energetic feeds; (ii) a significant portion of the research samples, especially fruits and vegetables, showed at least as much or higher DMD-OMD digestibility and metabolizable energy than roughages; (iii) a result showed that most of these research materials have an enough or much more macro and micro mineral concentrations for ruminant; (iv) using such waste fruit-vegetables or by-product sources as feed helps to reduce waste and minimize the adverse effect on the environment and their use will also decrease food-feed competition; (v) also using these feed sources in ruminant ration will raise the economic profitability and sustainability of the animal production.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

Table 1. Nutritional composition of the by-products feeds, waste fruits-vegetable and crop residue (g kg^{-1}, in DM)

	DM	Ash	OM	EE	CP	CF	NFE	NSC	NDF	ADF	Starch	Sugar
Apple Pomace	229^{g}	24^{j}	975^{a}	46.0^{e}	80.5^{ik}	315.8^{e}	533.0^{d}	259.7^{e}	589.1^{cd}	449.2^{d}	22.3^{c}	58.8^{d}
Carrot	117^{j}	79^{c}	920^{h}	10.6^{gh}	82.3^{i}	92.3^{jk}	734.7^{b}	683.2^{b}	143.8^{i}	135.9^{h}	-	235.0^{a}
Citrus Pulp	214^{hi}	44^{h}	955^{c}	14.7^{g}	92.9^{h}	137.6^{h}	710.5^{c}	644.0^{c}	204.2^{h}	174.5^{f}	91.4^{d}	220.6^{b}
Corn Stalk	935^{a}	54^{f}	945^{e}	8.1^{ghi}	61.2^{l}	352.1^{d}	523.8^{d}	109.8^{g}	766.0^{a}	494.0^{c}	-	25.3^{g}
Fig	850^{d}	37^{i}	962^{b}	35.5^{f}	66.1^{l}	76.6^{k}	783.9^{a}	731.0^{a}	129.6^{i}	109.5^{i}	-	235.1^{a}
Grape	858^{d}	69^{d}	930^{g}	12.1^{gh}	75.6^{k}	94.4^{j}	748.2^{b}	575.6^{d}	267.0^{g}	227.0^{e}	-	201.1^{c}
Grape Pomace	491^{e}	55^{f}	944^{e}	75.7^{d}	142.5^{d}	281.4^{f}	445.1^{f}	118.8^{g}	607.7^{c}	550.0^{b}	12.7^{gh}	49.1^{e}
Grape Stalk	293^{f}	74^{d}	925^{g}	24.2	104.3^{g}	252.3^{g}	544.6^{d}	218.5^{f}	578.3^{d}	545.6^{b}	25.7^{fg}	20.3^{gh}
Potato	205^{i}	61^{e}	938^{f}	3.3^{j}	131.6^{e}	19.4^{l}	783.9^{a}	660.3^{c}	143.0^{i}	22.1^{j}	642.0^{a}	31.1^{f}
Rice Bran	912^{c}	88^{b}	911^{i}	159.8^{b}	154.5^{c}	120.3^{i}	476.6^{e}	249.2^{e}	347.7^{f}	143.3^{h}	279.8^{b}	61.1^{d}
Rice Hull	926^{ab}	193^{a}	806^{j}	5.3^{hi}	39.0^{j}	506.2^{a}	255.3^{h}	16.2^{i}	745.4^{a}	645.3^{a}	12.7^{gh}	5.9^{j}
Soybean Hull	919^{bc}	46^{gh}	953^{cd}	15.2^{g}	125.0^{f}	411.7^{c}	401.5^{g}	117.3^{g}	696.0^{b}	538.4^{b}	61.7^{e}	22.2^{gh}
Tomato Pomace	222^{gh}	54^{f}	945^{e}	84.5^{c}	196.3^{b}	454.2^{b}	206.4^{i}	56.3^{h}	608.0^{c}	549.3^{b}	26.6^{f}	17.2^{h}
Whole Cotton Seed	929^{ab}	49^{fg}	950de	177.7^{a}	219.6^{a}	320.5^{e}	224.9^{i}	32.1^{i}	520.8^{e}	447.7^{d}	17.5^{fg}	19.7^{h}
SEM	31	3	4	5	4	14	18	25	21	19	16	8
P	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

^{a,k}Different superscripts indicate differences among the group means in the same row at p<0.05

Table 2. Mineral content of the by-products feeds, waste fruits-vegetable and crop residue

	Ca^1	P^1	Na^1	K^1	Mg^2	Fe^2	Cu^2	Mn^2	Zn^2
Apple Pomace	5.5^{gh}	1.6^{h}	0.8^{f}	8.6^{g}	1.2^{g}	257^{d}	57^{fg}	49^{g}	10.7^{f}
Carrot	6.4^{g}	2.3^{e}	5.3^{a}	24.9^{a}	2.2^{efg}	163^{fgh}	66^{de}	51^{fg}	24.4^{abc}
Citrus Pulp	17.3^{a}	1.2^{i}	0.5^{f}	12.5^{f}	1.4^{g}	175^{efgh}	62^{ef}	71^{defg}	8.8^{f}
Corn Stalk	6.5^{g}	1.1^{j}	0.5^{f}	12.4^{f}	2.5^{ef}	619^{a}	54^{g}	57^{fg}	9.1^{f}
Fig	7.9^{f}	1.1^{ij}	3.3^{c}	14.3^{e}	1.6^{fg}	141^{h}	57^{g}	66^{efg}	20.8^{bcd}
Grape	13.1^{d}	1.8^{g}	4.5^{b}	21.0^{b}	5.9^{b}	372^{c}	75^{b}	81^{cde}	19.7^{cd}
Grape Pomace	10.7^{e}	2.1^{ef}	1.4^{e}	17.7^{c}	1.9^{fg}	234^{def}	71^{bc}	55^{fg}	13.4^{ef}
Grape Stalk	15.9^{b}	2.0^{fg}	4.6^{b}	21.3^{b}	2.9^{de}	241^{def}	72^{bc}	133^{a}	25.2^{ab}
Potato	1.9^{i}	2.5^{d}	0.6^{f}	22.1^{b}	1.6^{fg}	277^{d}	59^{fg}	50^{fg}	16.6^{de}
Rice Bran	1.4^{j}	6.6^{a}	0.6^{f}	14.8^{de}	8.4^{a}	212^{defgh}	56^{g}	115^{ab}	23.1^{abc}
Rice Hull	5.3^{gh}	0.4^{k}	2.6^{d}	6.9^{h}	1.2^{g}	222^{defg}	66^{de}	91^{cd}	26.1^{a}
Soybean Hull	14.6^{c}	1.2^{i}	3.2^{c}	16.1^{d}	3.6^{d}	509^{b}	69^{cd}	72^{def}	19.7^{cd}
Tomato Pomace	8.0^{f}	4.0^{c}	4.4^{b}	17.5^{c}	5.8^{b}	253^{de}	80^{a}	99^{bc}	19.6^{cd}
Whole Cotton Seed	4.7^{h}	4.6^{b}	0.9^{f}	14.8^{de}	4.7^{c}	152^{gh}	67^{d}	15^{h}	16.6^{de}
SEM	0.4	0.1	0.2	0.4	0.2	14	0.8	3	0.6
P	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

[a,k]Different superscripts indicate differences among the group means in the same row at p<0.05
[1]$g\ kg^{-1}$, in dry matter
[2]$mg\ kg^{-1}$, in dry matter

Table 3. Dry and organic matter digestibility and metabolic energy content of the by-products feeds, waste fruits-vegetable and crop residue

	DMD%	OMD%	ME_{CN} kcal[1]	ME_{CEL} kcal[1]
Apple Pomace	75.7^{d}	73.9^{d}	2104^{g}	2391^{f}
Carrot	94.2^{ab}	92.3^{ab}	2702^{cd}	3072^{bc}
Citrus Pulp	96.0^{a}	95.5^{a}	2654^{d}	3112^{bc}
Corn Stalk	44.6^{g}	37.5^{h}	1755^{h}	1858^{h}
Fig	92.3^{b}	91.3^{b}	2983^{b}	3134^{b}
Grape	74.2^{d}	67.3^{e}	2729^{c}	2872^{d}
Grape Pomace	38.1^{h}	26.1^{i}	2275^{f}	2543^{e}
Grape Stalk	43.1^{g}	25.9^{i}	2131^{g}	1857^{h}
Potato	95.8^{a}	95.7^{a}	3052^{a}	2995^{c}
Rice Bran	74.9^{d}	68.5^{e}	3118^{a}	3310^{a}
Rice Hull	10.3^{i}	22.8^{i}	640^{j}	723^{j}
Soybean Hull	81.1^{c}	79.1^{c}	1556^{i}	2171^{g}
Tomato Pomace	66.2^{e}	59.0^{f}	1647^{i}	1296^{i}
Whole Cotton Seed	58.5^{f}	50.9^{g}	2532^{e}	2759^{d}
SEM	2.3	2.4	64	30
P	<0.05	<0.05	<0.05	<0.05

[a,j]Different superscripts indicate differences among the group means in the same row at p<0.05
[1]:$kcalkg^{-1}$, in dry matter

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