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# Determination of the usability of jam factory fruit-vegetable wastes in silage making

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**Abstract**

Recently, many countries have focused on utilizing industrial food residues to reduce environmental pollution. The utilization of waste products as animal feed is important in terms of being a cheap feed source and preventing environmental pollution. This study was carried out with the aim of preventing the waste from turning into garbage and increasing the feed value of the straw by making silage with wheat straw of the pulp and wastes left from the fruits and vegetables (strawberry, mulberry and carrot) used by the jam factory located in the organized industrial zone of Bingöl province. The residues of strawberry (S), mulberry (M) and carrot (C) were mixed with wheat straw (10%, 20% and 30%) and urea (0.5%) in different proportions and silaged using plastic drums. After an average fermentation period of 100 days, the silages were opened. The pH, dry matter (DM), fleig score values, ADF (Acid Detergent Fiber), NDF (Neutral Detergent Fiber), crude protein (CP), crude ash (CA), Ca, Mg, P and K contents were determined. As a result of the study, it was determined that the ideal pH values were obtained from S10 and S20 and the ideal DM values were obtained from S20, C10, C20 and C30 treatments and all treatments except C10 and C20 treatments were in the I-excellent class, which is the best value in terms of fleig score. It was determined that the lowest ADF and highest crude protein ratios were obtained from M10, the lowest NDF and highest crude ash ratios were obtained from M10, M20 and M30, the highest Ca and P ratios were obtained from S10 and C10, and the highest Mg and K ratios were obtained from all mulberry group silages. In line with this information, it was concluded that all three plant production wastes to which straw was added can be used in silage production.

**Keywords:** Strawberries, Mulberry, Carrots, Waste, Straw, Silage

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## INTRODUCTION

Recently, many countries around the world have focused on recycling industrial by-products to reduce environmental pollution (Mirzaei-Aghsaghali et al. 2011; Köksal et al., 2021). The use of agricultural by-products and food industry by-products with high water content as feedstuffs in animal nutrition after being dried or ensiled by various methods is also called alternative silage materials (FAO, 2013; Sargın and Denek, 2017).

Considering the industry, climate and vegetation of our country, there are many residues and by-products that can be utilized either as silage main material or as pulp material. Residues and waste of vegetables and fruits collected in fields and gardens, bark, stems, fruits and leaves of trees are products that can be used in silage production (İbrahimoğlu and Saruhan, 2019).

Fruit pulps obtained as a by-product in industrial production branches (fruit juice, jam, canned food) deteriorate in a short time under normal environmental conditions, making it impossible to use them in animal nutrition. For this reason, it is important to make silage of fruit pulps in terms of both their use in animal feeding and their utilization as a source of quality roughage (Yalçınkaya et al., 2012). Since fruits contain some important antioxidants, carotenoids, anthocyanins, anthocyanins, fatty acids, flavanoids and phenolic acids, and are rich in vitamins and minerals (Velioglu et al., 1998), their pulps also make important contributions to silage quality (Ülger et al., 2015).

Food factory residues such as apple, orange, lemon, tomato and grape pulp are used for silage production (Yalçınkaya et al., 2012). In many parts of the world, the use of industrial by-products such as tomato pomace, pomegranate pomace, grape pomace, citrus pomace, etc. in ruminant feeding has greatly increased as a result of increasing high-cost feeds (Besharati et al., 2017; Başar and Atalay, 2020). Şengul et al. (2021) reported that the addition of dried mulberry pulp to the ration can also be used without any problems.

The utilization of waste products as animal feed is important in terms of being a cheap feed source and preventing environmental pollution caused by waste (Özdemir and Okumuş, 2021).

Adsorbents such as cereals or straw can be added during ensiling to protect fruit and vegetable pulp and residues from deterioration and nutrient loss during storage periods and to increase dry matter ratios (Denek and Can, 2005; Sargın and Denek, 2017).

Straws cannot provide the needs of high-yielding animals due to their high cellulose, low nutrient content and digestibility (Gürsoy, 2023). However, straws are mostly used as a roughage source in animal nutrition; to close the roughage deficit, to ensilage plants with high water content and to give animals a feeling of satiety with its high lignin-cellulose content (Gemalmaz and Bilal, 2016; Gürsoy, 2023).

In Table 1, silage researches using fruit-vegetable pulps in the last 5 years are given together with their sources.

**Table 1.** Silage Researches Conducted With Fruit and Vegetable Wastes in the Last 5 Years in Turkey (Özdemir and Okumuş, 2021).

| Main material | Additives | Reference |
|---|---|---|
| Fresh tomato pulp | Molasses dry sugar beet pulp | (Sargin and Denek, 2017) |
| Orange, tangerine, lemon, maize straw, beet pulp | - | (Beyzi et al., 2018) |
| Maize | Pistachio husk | (Paydaş, 2019) |
| Lathyrus | Apple, lemon, pear | (İbrahimoğlu and Saruhan, 2019) |
| Citrus Pulp | - | (Başar and Atalay, 2020) |
| Alfalfa | Waste jam | (Yayla and Soycan Önenç, 2021) |
| Meadow grass | White mulberry pulp | (Köksal et al., 2021) |

Examining Table 1 and the studies in the literature, it was seen that apple, peach and citrus pomace were generally used in silages made with organic wastes, strawberry and carrot were not encountered, and white mulberry pomace was found in very few studies, but the silage formed with straw was not tried.

Considering that the fruit-vegetable pulps that occur as by-products in industrial production branches (fruit juice, jam, canned food) deteriorate in a short time under normal environmental conditions and also considering that mulberry molasses is a tradition especially for the region, not only for factory residues but also as a result of this traditional production, mulberry pulp is produced every year; in this study, it was aimed to prevent the waste of the leftovers of the fruits and vegetables (strawberries, carrots and, mulberries) used by a jam factory located in the organized industrial zone of Bingöl province during the year from being thrown away and to be used in silage production with a product with low feed value such as straw.

## MATERIALS AND METHODS

The factory has about 1200 kg of strawberry, 100 kg of carrot and 97 kg of mulberry pulp left over from the strawberries, carrots and mulberries that are cleaned for jam making each season, which the factory disposes of as garbage. In the experiment, strawberry, carrot and mulberry residues used for making the silages were obtained from the factory and wheat straw and urea were obtained commercially. Wheat straws contain 1-2% digestible crude protein, over 50% crude cellulose, 1-2% crude fat and 28-50% N-free extracts in its dry matter, but it is very deficient in mineral and vitamin content (Ak and Akbay, 2018). In addition, some nutrient contents of wheat straw are presented in Table 2.

**Table 2.** Some Nutrient Contents of Wheat Straw (%).

| **Straw type** | **Dry matter** | **CP** | **Crude cellulose** | **Crude ash (CA)** | (Gürsoy, 2023) |
|---|---|---|---|---|---|
| **Wheat** | 92.4 | 4.1 | 37.1 | 16.4 | |
| **Straw type** | **Digestible dry matter** | **CP** | **ADF** | **NDF** | (Çaçan and Kökten, 2023) |
| **Wheat** | 53.9 | 5.18 | 45 | 70.5 | |

Urea is used to enrich silage in terms of nutrients and to increase the nitrogen content of silage (Yalçınkaya et al., 2012). In addition, straws are also treated with urea to increase their feed value and to use them effectively in rations (Gürsoy, 2023). Silages were prepared in 3 replicates, using 0.5% urea and grouped in the ratios and mixtures indicated in Table 3 (Table 3).

In the preliminary experiment, when more than 30% straw was added, the ratio of fruit and vegetable wastes in the mixture was very low and the moisture to ensure fermentation was found to be insufficient. For these reasons and in order not to exceed the desired 35% dry matter rate in silages, the straw ratios in the mixtures were determined as 10%, 20% and 30%.

**Table 3.** Silage Groups and Straw Ratios Formed in The Experiment

| | **Groups** |
|---|---|
| 1. | **S10**: Strawberry waste + 10% straw |
| 2. | **S20**: Strawberry waste + 20% straw |
| 3 | **S30**: Strawberry waste + 30% straw |
| 4. | **C10**: Carrot waste + 10% straw |
| 5 | **C20**: Carrot waste + 20% straw |
| 6. | **C30**: Carrot waste + 30% straw |
| 7. | **M10**: Mulberry waste + 10% straw |
| 8. | **M20**: Mulberry waste + 20% straw |
| 9 | **M30**: Mulberry waste + 30% straw |

The periods when the wastes consisting of strawberries, carrots and mulberries obtained by the factory during the season were followed. These residues were mixed with straw and urea at the determined ratios in plastic containers and filled in an airtight container (Figure 1).

**Figure 1.** Images of Carrot, Strawberry and Mulberry Wastes Used in Silage Preparation.

The silages were left for fermentation for an average of 100 days.

**Analysis and Evaluation of Silage Samples**

At the end of the waiting period, the silages were opened and pH and dry matter (DM) were determined. After drying, the silage samples were ground to pass through a 1 mm sieve and stored in a nylon bag to prevent moisture absorption.

Acid detergent insoluble fiber (ADF), neutral detergent insoluble fiber (NDF), crude ash content and crude protein content of the samples were determined by NIRS (Near Infrared Spectroscopy).

Determination of Silage pH Content: In order to determine the pH value of silages, 25 g of silage sample was taken from each bin and homogenously mixed, weighed to 0.01 g on a sensitive scale and placed in the mixer. After the sample was homogenized by adding 100 ml of pure water and mixed in a magnetic mixer for 5 minutes, 30 ml of the mixture was filtered and the pH of this filtrate was measured with a digital pH meter (Polan et al., 1998).

Dry Matter (%): Approximately 50 g silage samples were placed in tared containers and dried at 70 °C for 4-5 days until thoroughly dried. At the end of the drying process, the container containing silage material was weighed. Dry matter content of silages formula (AOAC, 1990):

$$\mathrm{DM\%} = 100 - \mathrm{Moisture\%} \quad \text{(I)}$$

$$\%\,\mathrm{Moisture} = ((A1 - D) - (A2 - D)) \,/\, A1 * 100 \quad \text{(II)}$$

(A1: Silage + container tare (g), D: Container tare (g), A2: Dry matter + container tare (g))

Fleig Score: It is a scoring system used to determine silage quality by using the KM and pH contents of silage material. Fleig Score was calculated as follows (Kılıç, 1986).

$$\text{Fleig Score} = [220 + (2 \times \% \text{DM} - 15)] - 40 \times \text{pH} \quad \text{(III)}$$

The Flieg score obtained from the above equation was used to classify the quality of the silages according to the score criteria given by Nauman and Bassler (1993) and Yalçınkaya et al. (2012) (0-20; V-Bad, 21-40; IV- Low, 41-60; III- Medium, 61-80; II- Good, 81-100; I- Excellent).

Determination of ADF, NDF, crude protein (CP) and crude ash (CA) ratios: Determined with the help of NIRS (Near Infrared Spectroscopy) device.

Statistical Analysis: Analysis of variance (ANOVA) was performed on all data obtained by measurements and analyzes in the study and the averages obtained were compared with Tukey test (5%) (JMP 13.2.0).

## RESULTS AND DISCUSSION

### pH, Dry Matter and Fleig Score

pH, KM and Fleig scores of silages made with jam factory wastes (strawberry, carrot and mulberry residues) and wheat straw are given in Figure 2. Among the analyzed traits, pH, KM and Fleig score were found to be statistically very significant (P<0.01).

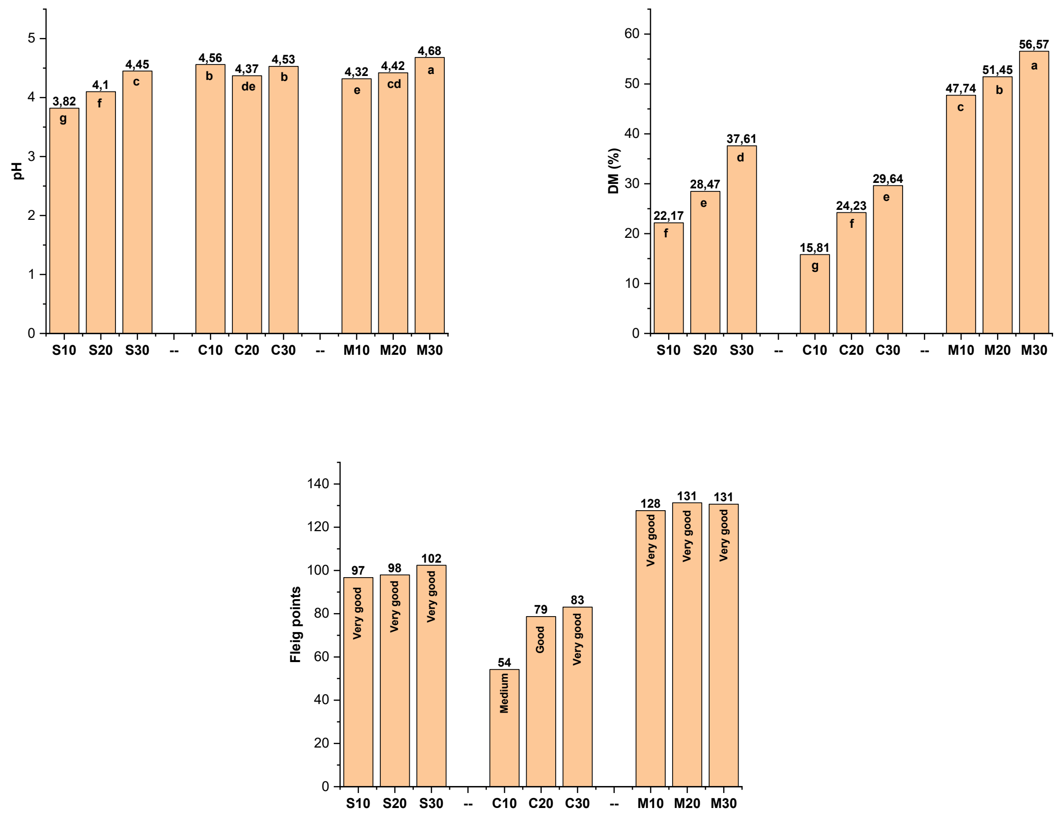


**Figure 2.** pH, KM and Fleig Scores of Silages Made From Strawberry, Carrot and Mulberry Residues.

The lowest pH value (3.82) was determined in the S10 group, while the highest pH value (4.68) was determined in the M30 group. The desired pH levels in a quality silage are in the range of 3.80-4.30 (Mafakher et al., 2010; Ülger et al., 2020). In this context, among the silage groups, only the 10% and 20% straw added group made with strawberry residues was at the desired pH level. The pH values of fruit-vegetable residues affected the silage pH value. Oğuz and Pırlak (2019) reported that some strawberry juice pH levels were in the range of 3.09-3.63, Kiracı and Padem (2015) reported the average pH value of carrot juice as 6.61, and Budak (2015) reported the pH value of white mulberry juice as 6.04. Ülger et al. (2015) determined pH values in the range of 3.59-4.35 in apple, lemon, orange, tangerine and peach silages made by silaging fresh beet pulp with fruit juice industry residues. Başar and Atalay (2020) found pH values in the range of 2.72-3.48 in crusted and uncrusted citrus silages. Kızılşimşek et al. (2011) reported that the pH level of alfalfa silage was significantly reduced with the addition of fruit pulp in their study.

The lowest DM value (15.81 g) was determined in C10 silage group while the highest DM value (56.57 g) was determined in D30 group. In all silage groups, the increase in the straw ratio caused an increase in the DM ratio. Only four silage groups (S20 and C10, C20, C30) were within the average DM (25-35%) content range reported for silages (Kaynar and Atalay, 2023). Klamem et al. (2005) and Panyasak and Tumwasorn (2015) reported that dry matter content should be between 25-40% for a silage to be considered as good quality. A dry matter content of more than 40% means a high cellulose and hemicellulose content in the feed, which makes it difficult to digest and reduces its taste. In addition, high dry matter content makes it difficult to compress the silage, requiring more precise ensiling to eliminate the risk of spoilage. On the other hand, low dry matter content reduces the carbohydrate content of silage and causes spoilage (Panyasak & Tumwasorn, 2015; Burgu & Mut, 2023). The DM content of the silages formed by ensiling different ratios of molasses dry sugar beet pulp and tomato pulp varied between 21.48-35.10% (Sargın & Denek, 2017). Yalçınkaya et al. (2012) found DM content in the range of 32.93-35.03% in silages made by mixing apple, peach and apricot pomace with straw.

The quality classification of the silages was made according to the Flieg score obtained and the score criteria given by Nauman & Bassler (1993) and Yalçınkaya et al. (2012) and presented in Figure 2. The silages belonging to C10 straw group were in III-medium class, C20 straw group was in II-good class and all other silage groups were in I-excellent class. Since DM and pH values were used in the calculation of fleig score, since straw increased the DM ratio, fleig scores were found to be high accordingly. Yalçınkaya et al. (2012) stated that the fleig scores of straw and urea added groups were higher in apple, peach and apricot silages. In silages made by mixing strawberry, carrot and mulberry residues with straw, fleig scores varied between 54.21 and 131.29. İbrahimoglu and Saruhan (2019) found fleig scores between 76.22-85.12 in silages made with apple, pear and lemon fruits added at various rates of damson plant. Seydoşoğlu and Gelir (2019) found the highest fleig score of 109.23 in silages made with different ratios of damson and barley mixture. It is seen that these results obtained by the researchers are partially similar to the results of this study.

**ADF, NDF, CP and CA values (%)**

ADF, NDF, CP and CA values of silages made with jam factory wastes (strawberry, carrot and mulberry residues) and wheat straw are given in Figure 3. Among the analyzed traits, ADF, NDF, CP and CA were found to be statistically very significant (P<0.01).

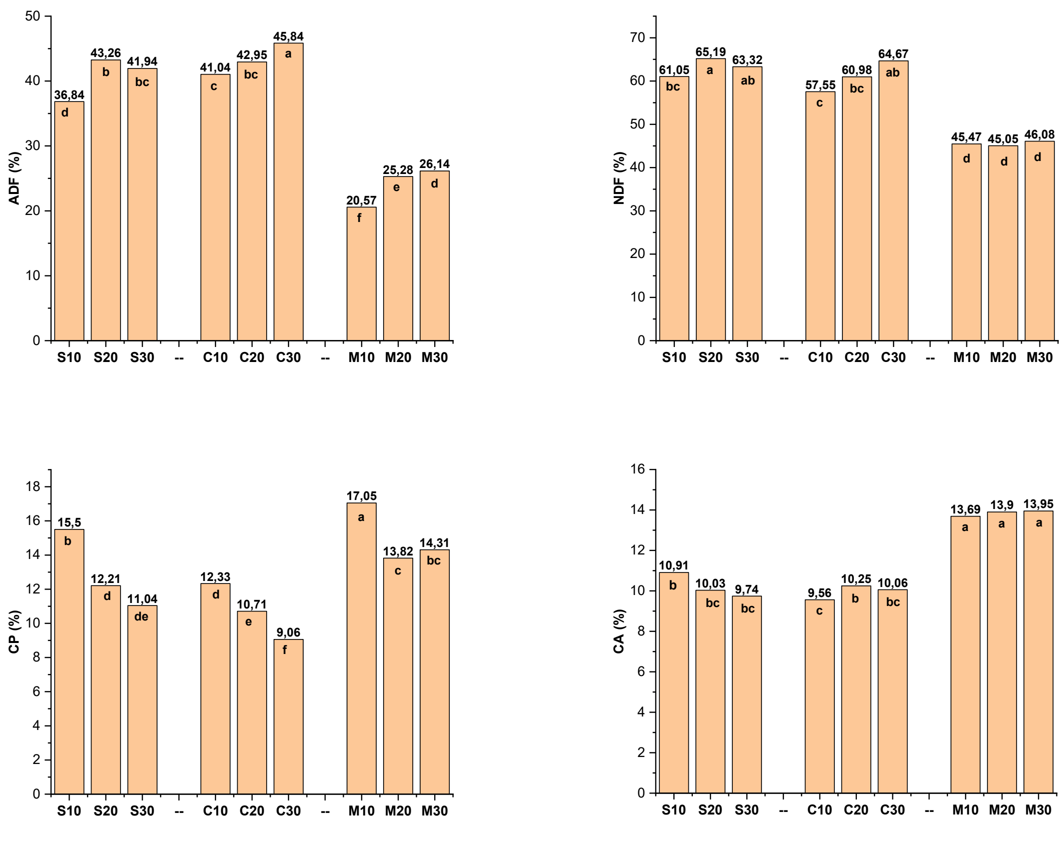


**Figure 3.** ADF, NDF, CP and CA Values of Silages Made From Strawberry, Carrot and Mulberry Residues.

The addition of straw to vegetable and fruit wastes caused an increase in ADF ratios in all silage groups. The lowest ADF rate (20.57%) was obtained in M10 group and the highest ADF rate (45.84%) was obtained in C30 group. ADF ratio is an important parameter that gives information about the degree of digestibility of silages and the higher the ADF ratio, the lower the degree of digestibility of that feed (Erişci et al., 2022). Acikbas and Ozyazici

(2019) reported that the average ADF rate in wheat straw was 52.31%. It is seen that especially mulberry residues help to decrease the ADF rate of straw. Doğan (2019) reported that the ADF content of silages decreased with the addition of apple pulp.

The lowest NDF ratios (45.05-46.08%) were obtained in silages containing 10%, 20% and 30% straw made with mulberry wastes, while the highest NDF ratio (65.19%) was obtained from the S20 straw group. The highest NDF ratios were found in the strawberry residue group, which is thought to be due to the fact that most of the strawberry residues consisted of sepals of strawberry fruit. Wardiny et al. (2021) found 40.8% NDF in Morinda citrifolia fruits, while in leaves they found 50.1%, higher than the fruit.

While the lowest crude protein content was determined in C30 silages, the highest crude protein content was determined in M10 silages. Mulberry group silages had a higher protein ratio than the other groups. This is thought to be due to the fact that strawberry residues were mostly composed of sepals, carrot residues were mostly composed of carrot stems, and mulberry residues contained the seeds of the fruit. Mulberry pulp (MP) is a by-product of mulberry juice production such as jam, molasses, etc. and consists of the seeds and peeled parts of the mulberry (Elmacı and Altuğ 2002). Kır and Temel (2017) found that the crude protein ratios in the seeds of the plants were higher than the plant stems. Carrot group silages had lower crude protein content. Kaya and Kamalak (2019) examined the nutrient composition of root and tuberous market residues and found that the crude protein content of carrot was considerably lower than other plants.

The lowest crude ash content (9.56%) was obtained in silages containing C10, while the highest crude ash content (13.69-13.95%) was obtained from silage groups containing 10%, 20% and 30% straw made with mulberry residues. Similar results for crude ash ratios were obtained in apple pomace silages added to alfalfa silages (Ünal et al., 2024) and residual jam particles silages added to alfalfa silages (Yayla and Soycan Önenç, 2021).

**Ca, Mg, P and K contents of silages (%)**

Ca, Mg, P and K values of silages made with jam factory wastes (strawberry, carrot and mulberry residues) and wheat straw are given in Figure 4. The differences between Ca, Mg, P and K values were found to be statistically very significant (P<0.01).

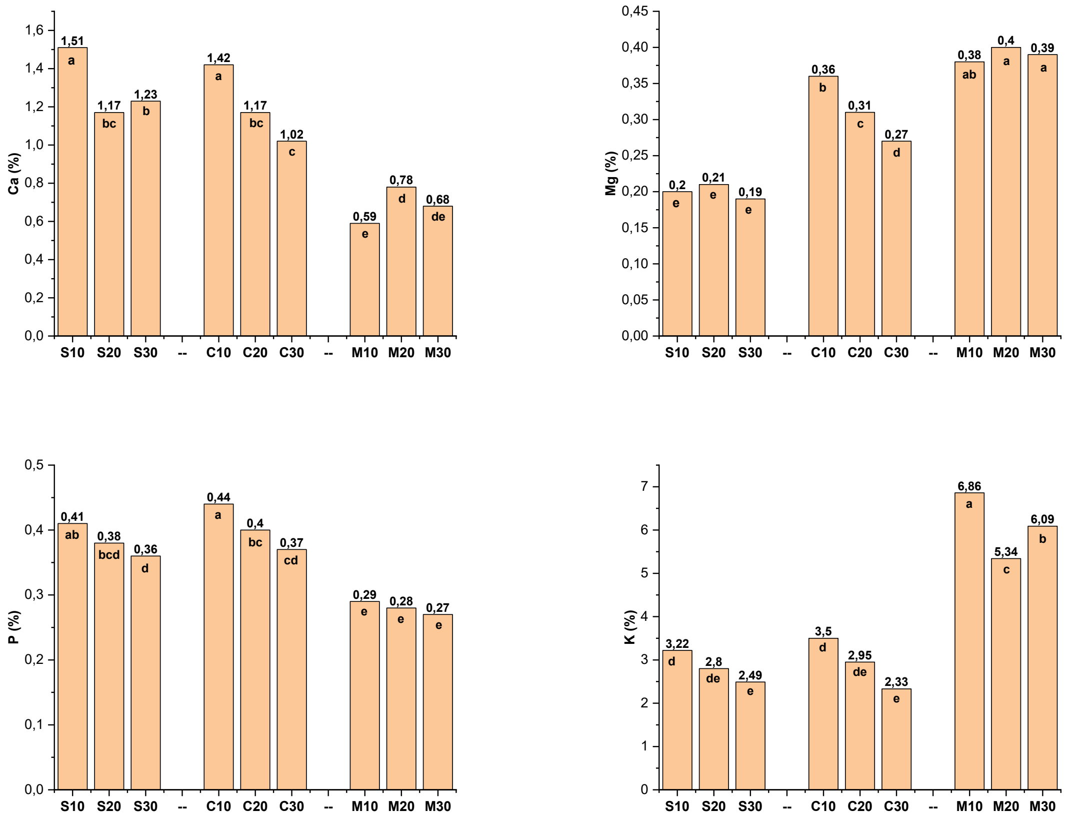


**Figure 4.** Ca, Mg, P and K Contents of Silages Made From Strawberry, Carrot and Mulberry Residues.

The Ca content of the silages varied between 0.59% and 1.42%. The silage group with the lowest Ca content was M10, while the groups with the highest Ca content were S10 and C10. In terms of ruminant health, Ca content of quality roughages should be between 0.18 - 0.44% (Kidambi et al., 1989; Burgu and Mut, 2023).

The Mg content of silages varied between 0.19%-0.40%. The lowest Mg content was in the S30 group and the highest Mg content was in the M20 group. It has been reported that magnesium content in feeds should be between 0.12% and 0.20% for healthy animal breeding (Anonymous, 1980; Başbağ et al., 2018).

The silage groups met the minimum recommended Ca and Mg contents in forages and also had Ca and Mg contents above the maximum recommended Ca and Mg contents. Jones et al. (1991) reported that some forage crops such as sorghum and maize had Ca and Mg contents of 0.20-0.30 and 0.10-0.15%, respectively, while strawberries and carrots had at least 1% for Ca and Mg, respectively. It is thought that Ca and Mg ratios are lower in ensiled plants than in fruits and vegetables and the ratios recommended for silage are generally determined according to the nutrient content of the silage plants. In this study, it is thought that fruit and vegetable wastes increased the Ca and Mg content of silages, resulting in higher ratios.

While the P contents of the silages varied between 0.27%-0.44%, the group with the highest P content was C10. K content of silage groups varied between 2.33%-6.86%. While the silage group with the lowest K content was C30, the group with the highest K content was M10 straw.

Forages for ruminants should have a P content of at least 0.21% (Kidambi et al., 1989) and a K content of at least (Tejada et al., 1985) 0.8%, (Mut et al., 2020). In all silage groups obtained by mixing strawberry, carrot and mulberry residues with straw at different ratios, P and K contents were found to have the ratios required by the researchers.

## CONCLUSION

In this study in which the usability of jam factory fruit and vegetable wastes for silage production was investigated, it was observed that the ideal pH values were obtained from S10 and S20 and the ideal DM values were obtained from S20, C10, C20 and C30 treatments. It was determined that all treatments except C10 and C20 treatments were in the I- excellent class, which is the best value in terms of fleig score. The lowest ADF and highest crude protein ratios were obtained from M10, the lowest NDF and highest crude ash ratios were obtained from M10, M20 and M30 treatments. In terms of macro elements, the highest Ca and P ratios were obtained from S10 and C10, and the highest Mg and K ratios were obtained from M10, M20 and M30 treatments. In accordance with this information, it was concluded that all three crop production residues to which straw was added can be used in silage making.

**Compliance with Ethical Standards**

**Peer-review**

Externally peer-reviewed.

**Declaration of Interests**

There is no conflict of interest between the authors in this study.

**Author contribution**

Conception and design of the study: HŞİ, ST, EÇ, Eİ; sample collection: HŞİ, Eİ; analysis and interpretation of data: HŞİ, EÇ ; statistical analysis: HŞİ, EÇ; visualization: HŞİ, ST,EÇ; writing manuscript: HŞİ, EÇ.

**Ethics committee approval**

We declare that there is no need for an ethics committee for this research.

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