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Original Article

Effects of Wheat Bran and Molasses Additives on Quinoa Silage Quality

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ABSTRACT

This study was carried out to determine the effects of different additives (molasses and wheat bran) and their rates (0%, 5%, 10% and 15%) on the silage quality of quinoa (*Chenopodium quinoa* Willd.). Molasses and wheat bran had significant effects on quality characteristics of quinoa silage. Molasses and wheat bran increased the dry matter rate, crude protein, lactic acid and propionic rates of quinoa silage, while pH, ammonia, crude ash and acetic acid contents decreased. While molasses had no effect on the ADF (acid detergent fibre) rate, wheat bran caused an increase in the ADF rate. While wheat bran caused a significant increase in the NDF (neutral detergent fibre) rate compared to the control, molasses caused a decrease in the NDF rate. While molasses significantly increased the RFV value, wheat bran caused a decrease in the RFV (relative feed value). While the butyric acid rate was high only in the 5% wheat bran application, no significant difference was observed in other applications compared to the control.

Key words: Organic acid, lactic acid, dry matter, pH, crude protein, neutral detergent fibre

Kinoa Silaj Kalitesine Buğday Kepeği ve Melas Katkı Maddelerinin Etkileri

ÖZ

Bu çalışma, farklı katkı maddelerinin (melas ve buğday kepeği) ve bunların oranlarının (% 0, % 5, % 10 ve % 15) kinoa (*Chenopodium quinoa* Willd.) silaj kalitesi üzerine etkilerini belirlemek amacıyla yürütülmüştür. Melas ve buğday kepeği kinoa silajının kalite özellikleri üzerine önemli etkilere sahiptir. Melas ve buğday kepeği kinoa silajının kuru madde oranını, ham proteini, laktik asit ve propiyonik oranlarını artırırken, pH, amonyak, ham kül ve asetik asit içeriklerini azaltmıştır. Melas ADF (asit çözücülerde çözünmeyen lif) oranı üzerine etki etmezken, buğday kepeği ADF oranında artışa neden olmuştur. Buğday kepeği NDF (nötr çözücülerde çözünemeyen lif) oranında kontrole göre önemli artışa neden olurken, melas NDF oranında azalmaya neden olmuştur. Melas NYD (nispi yem değeri) değerini önemli ölçüde artırırken, buğday kepeği NYD'de azalmaya neden oldu. Bütirik asit oranı sadece %5 buğday kepeği uygulamasında yüksek iken, diğer uygulamalarda kontrole kıyasla önemli bir fark gözlenmedi.

Anahtar kelimeler: Organik asit, laktik asit, kuru madde, pH, ham protein, nötr çözücülerde çözünemeyen lif

INTRODUCTION

Silage is an important feed source in animal nutrition. Silage is the feed made to meet the roughage needs of animals during the winter months when roughage and green feed are scarce and grazing is not possible. Silage has an important place in meeting the green feed needs of animals in winter. Silage is becoming increasingly widespread due to reasons such as its high digestion rate, its consumption with pleasure by animals, its long shelf life and low loss of nutrients, its high water content and most importantly, its economical nature. Corn, alfalfa, meadow grass, sainfoin, barley grain, sorghum and sunflower plants are generally used in silage making. The number of plants that are resistant to extreme climate and soil conditions such as salty and arid and which can be preferred for silage making is limited. Quinoa plant, which is resistant to salty, cold and dry conditions, has the potential as an alternative plant for silage production in extreme climate and soil conditions (Razzaghi, 2011; Jacobsen, 2003; Keskin et al., 2023). Quinoa is an annual and dicotyledonous plant belonging to the *Chenopodiaceae* family.

Depending on the ecological and soil conditions of the region, plant height varies between 50-350 cm (Kadereit et al., 2005; Temel and Keskin, 2022). Quinoa is now widely grown in China, India, America and Canada. The fact that the United Nations declared 2013 the "Year of Quinoa" and that the National Aeronautics and Space Administration included quinoa seeds in the astronauts' food list made a significant contribution to the spread of quinoa (Kır and Temel, 2016; Geren and Güre, 2017). Quinoa has the potential as an alternative feed source for animals due to its high seed and dry matter yield per unit area (Keskin and Önkür, 2019, Temel and Keskin 2019). The straw, harvest residues, green parts and silage of the quinoa plant are used in animal nutrition (Van Schooten and Pinxterhuis, 2003; Kakabouki et al., 2014; Podkòwka et al., 2018; Yacout et al., 2021; Salama et al., 2021).

Since quinoa has low carbohydrate content and high water content, making silage without using additives will result in poor silage quality. Therefore, using additives that will increase the dry matter content and fermentation of quinoa silage will increase the quality of quinoa silage. Barley grain, urea, molasses, salt, cracked wheat, wheat bran, cracked barley and whey are generally used as additives to silages (Gülümser et al., 2019). Molasses and cracked wheat additives contribute significantly to increasing silage quality (Kordi and Naserian, 2012; Qin and Shen, 2013).

This study was conducted to determine the effects of molasses and wheat bran used as additives on the silage quality of quinoa.

MATERIALS AND METHODS

Silage material was taken at Iğdır University Agricultural Application and Research Center in the field of Red Head variety of quinoa grown under irrigated conditions in 2022 year. The quinoa plant in this area was sowed with a row spacing of 35 x 10 cm and row spacing, and 80 kg ha^{-1} of phosphorus and 7.5 kg of nitrogen were given with the sowing. When the plants were 30-40 cm tall, an additional 50 kg ha^{-1} of nitrogen was given. Plant chopped theoretically 2-4 cm length and ensiled by using plastic vacuum packed, and approximately 400 g of fresh forage material was placed into the plastic silage bags. Molasses and wheat bran were added to the silage samples at the rates of 5%, 10% and 15%. No additives were added to the control silages. Silage samples were kept in a dark place for fermentation for 60 days. Each application was prepared in 3 replicates. Silage samples were opened after 60 days and subjected to the following silage quality analyses.

pH: 20 grams of mature silage samples were put into the blender together with the wet silage sample and 180 ml of pure water and mixed well. It was then passed through a cloth filter to remove solids and the pH of the filter was determined with a pH meter (AOAC 1990).

Dry matter rate: 20 grams of mature silage samples were taken and placed in aluminum containers and dried in drying ovens set at 65 °C until their weight stabilized. The dry matter rate was determined by dividing the initial wet weight (AOAC 1990).

Ammonia: The amount of ammonia was determined by applying the titration and distillation stages of the Kjeldahl method, which is used to determine the amount of nitrogen in the silage filter used in pH measurement (AOAC 1990).

Crude protein rate: The amount of nitrogen was determined using the micro Kjeldahl method, and the amount of protein was determined by multiplying the amount of nitrogen by 6.25 (AOAC 2003).

Crude ash rate: After the samples were kept in the muffle furnace set at 550 °C for 8 hours, the amount of ash was determined by proportioning the remaining amount to the initial amount (AOAC 1990).

NDF and ADF rate: It was determined according to the method specified by Van Soest et al. (1991).

Relative feed value: %KMS (Dry Matter Digestibility = 88.9 - (0.779 * % ADF) was determined by using the ADF rate and %KMT (Dry Matter Consumption = 120 / % NDF) was determined by using the NDF rate. By multiplying the KMT and KMS values and dividing by 1.29 NYD value was also determined (Sheaffer et al. 1995).

Organic Acids: The amounts of lactic acid, propionic acid, acetic acid and butyric acid, among the silage organic acids were determined using the method specified by De Baere et al. (2013) on the HPLC-DAD device.

Research data were analyzed for variance in the SPSS Statistics 17.0 statistical program, and important factor averages were grouped according to the Duncan test (SPSS, 2008).

RESULTS AND DISCUSSION

The effects of wheat bran and molasses additives on the pH, dry matter, ammonia, crude protein, crude ash, NDF, ADF, RFV, lactic acid, acetic acid, propionic acid and butyric acid amounts of quinoa silage were determined.

pH

When the control, molasses additive, wheat bran additive and molasses + wheat bran additive were examined in quinoa silage, pH values were found between 3.90-5.23. The highest pH value (5.23) was detected in quinoa silages without additives. In control silage, Podkòwka et al. (2018), Yacout et al. (2021), Güner and Temel (2022) and Salama et al. (2021) determined pH values of 4.13, 4.36, 4.23 and 4.36, respectively, and while these values were found to be higher than the pH values obtained in our current study, the pH value (5.65) determined by Fang et al. (2022) was low. When molasses and wheat bran were added, silage pH values varied between 3.0 and 4.80. Additives caused the pH value of quinoa silage to decrease. The addition of 15% wheat bran and 10% molasses contributed more to the decrease in silage pH. It has been reported that the use of additives such as molasses, wheat bran, and crushed wheat causes significant decreases in the pH value of silages (Qin and Shen 2013, Silva et al. 2014, Bolakar and Yüksel 2021, Fang et al. 2022, Gül 2023). When wheat bran was used at 15% and molasses additive was used at 5%, 10% and 15% rates, silage pH values were found to be between 3.90-4.00 and close to the optimum silage pH values of 3.80-4.20 (Leterme et al. 1992). McDonald et al. (1991) and Limin Kung et al. (2003) stated that molasses, which contains high amounts of water-soluble carbohydrates, causes the pH value of silages to decrease because it accelerates the activity of lactic acid bacteria and prevents the conversion of proteins in the silage to ammonia. The food source of lactic acid bacteria is soluble sugars. Silage materials containing sufficient amounts of sugar cause lactic acid bacteria to multiply and ultimately decrease the pH value of the silage. In silages that do not contain enough sugar, rotting, putrefaction and mold occur in silages due to slow fermentation and pH value not decreasing (Çiftçi et al., 2005; Şakalar and Kamalak, 2016).

Dry Matter Rate (%)

The dry matter rate in the control silage was determined as 15.43%. In control silages of quinoa, Podkòwka et al. (2018), Salama et al. (2021), Pulido Suarez et al. (2019) and Güner and Temel (2022) determined the dry matter rates as 20.93%, 26.89%, 16.9% and 24.39%, respectively, and found them lower than the values in our current study. On the other hand, Fang et al. (2022), the dry matter rate of the control quinoa silage (10.7%) was higher than our current finding. Using increasing amounts of wheat bran, molasses and molasses + wheat bran additives increased the dry matter rate of quinoa silage. If additives were added, dry matter rates varied between 16.93% and 32.20%. The highest dry matter rate (32.2%) was obtained in the application where the highest amount of additives were used (15% M and 15% WB). As a matter of fact, in studies conducted on different plant silages, it was reported that additives such as molasses, wheat bran, broken wheat and cracked barley caused significant increases in the silage dry matter rate (Kordi and Naserian, 2012; Silva et al., 2014; Dumlu Gül et al., 2015; Bolakar and Yüksel, 2021; Fang et al., 2022; Gül 2023).

Ammonia (%)

The ammonia content of quinoa silage without additives was 11.10%. Podkòwka et al. (2018), Salama et al. (2021), Güner and Temel (2022) and Yacout et al. (2021) determined the ammonia rates in quinoa silage as 8.02%, 1.27%, 5.51% and 1.27%, respectively, and these values were found to be higher than the values obtained in our current study. On the other hand, it was found to be lower than the values (22.90%) determined by Fang et al. (2022). When wheat bran additive was used in quinoa silage, ammonia levels were found to be between 4.56-15.06%. While using 5% wheat bran increased the ammonia content compared to the control, adding higher amounts of wheat bran (10% and 15%) to quinoa silage significantly reduced the ammonia content. As a matter of fact, in studies conducted, different researchers determined that when wheat bran additive was used in silages, the ammonia rate decreased compared to the control group (Silva et al., 2014; Qin and Shen, 2013). When molasses additive was used in quinoa silage, ammonia levels were found to be between 5.26-9.20%. Due to the increase in the molasses additive rate, decreases in the ammonia rate were also observed. As a matter of fact, in studies conducted on different plants, it was determined that the addition of molasses caused a significant decrease in the ammonia content of silage (Fang et al., 2022; Gül 2023). When molasses + wheat bran additives were used together, the ammonia levels of quinoa silage were found to be between 2.73-7.86%. The application that reduced the ammonia rate the most in quinoa silage was 10% molasses + 15% wheat bran additives.

Crude Protein Rate (%)

Crude protein content in quinoa silage without additives was determined as 16.10%. Crude protein values of quinoa silage were determined as 17.60% and 16.67%, respectively, by Güner and Temel (2022) and Fang et al. (2022). These detected values were similar to our current study. On the other hand, crude protein values were determined by Podkòwka et al. (2018), Pulido Suarez et al. (2019) and Yacout et al. (2021) as 10.31%, 15.10% and 14.59%, respectively. These values were found to be higher than our current study. When wheat bran additive was used, crude protein rates were found to be between 15.93%-17.60%. The use of increasing amounts of wheat bran has caused a decrease in the crude protein content of silage. As a matter of fact, in studies conducted on different plant silages, many researchers found that using additives such as wheat bran, wheat cracked, barley cracked or barley paste caused a decrease in the crude protein rate (Dumlu Gül et al., 2015; Acar and Bostan, 2016, Gülümser et al., 2019, Gül, 2023). When molasses additive was used, crude protein rates were found to be between 15.80-20.23%. The addition of molasses caused an increase in the crude protein content of quinoa silage. However, the high use of molasses (15%) caused a decrease in the crude protein rate. It has been reported that adding molasses to silages made with different plant species causes decreases in the crude protein rate (Canbolat et al., 2019; Gülümser et al., 2019). This may be related to the crude protein content of the plant. As a matter of fact, it has been determined that adding molasses to the silage of the alfalfa plant, which has a high protein content, causes decreases in the crude protein rate (Acar and Bostan, 2016). On the other hand, some studies have determined that the addition of molasses increases the crude protein rate of silage (Bolakar and Yüksel, 2021; Fang et al., 2022; Gül, 2023). It has been observed that when molasses + wheat bran are used together, crude protein rates vary between 15.96% and 18.76%. While the crude protein content was high in applications with 5% and 10% molasses content, it was observed that there were decreases in the crude protein content due to the increase in the wheat bran content.

Table 1. Effects of molasses (M) and wheat bran (WB) additives on quinoa silage quality

Application	pH	Dry matter (%)	Ammonia (%)	Crude protein (%)	Crude ash (%)
Control	5.23 a	15.43 i	11.10 b	16.10 d	27.76 a
5% WB	4.80 b	17.43 ı	15.06 a	15.93 d	22.70 c
10% WB	4.10 c	22.06 f	5.43 e-g	17.16 cd	16.90 e
15% WB	4.00 d	25.53 d	4.56 f-ı	17.60 b-d	15.46 f
5% M	4.00 d	16.93 ı	9.20 c	19.46 ab	24.00 b
10% M	3.90 e	18.76 h	7.90 cd	20.23 a	23.10 bc
15% M	3.90 e	21.93 f	5.26 e-h	15.80 d	22.10 c
5% M x 5% WB	4.00 d	21.13 g	7.86 cd	18.30 bc	19.96 d
5% M x 10% WB	3.90 e	24.13 e	4.00 f-ı	18.16 bc	17.13 e
5% M x 15% WB	3.93 e	27.63 c	3.50 hı	15.96 d	14.83 f
10% M x 5% WB	3.90 e	22.40 f	5.76 ef	18.76 a-c	19.36 d
10% M x 10% WB	3.90 e	25.46 d	3.16 ı	17.50 cd	17.06 e
10% M x 15% WB	3.90 e	29.63 b	2.73 ı	17.53 cd	14.53 f
15% M x 5% WB	3.90 e	25.23 d	6.90 de	16.86 cd	18.93 d
15% M x 10% WB	3.90 e	28.20 c	4.46 f-ı	15.96 d	16.73 e
15% M x 15% WB	3.90 e	32.20 a	3.73 g-ı	16.23 d	14.46 f
F value and significance	1012.9**	446.2**	61.5**	5.4**	93.1**

**P<0.01[a,b,c] Means within a row with different letters differ by Duncan test.

Crude Ash Rate (%)

The raw ash rate of silage without additives was determined as 27.76%. This value was determined by Podkòwka et al. in studies conducted to determine the crude ash rate in quinoa silage. (2018), Pulido Suarez et al. (2019), Yacout et al. (2021) and Güner and Temel (2022) were found to be higher than the values reported (14.76%, 16.70%, 9.42% and 26.37%). When wheat bran additive was used, crude ash rates were found to be between 15.46-22.70%. The addition of wheat bran caused a decrease in the crude ash content. Studies conducted by some researchers have found that adding wheat bran or crushed wheat to silages reduces the crude ash rate (Kordi and Naserian, 2012; Gül, 2023). When molasses additive was used, crude ash rates were found to be between 22.10-24.00%. The highest value of raw ash rate was obtained with the addition of 5% molasses. The addition of molasses at higher rates (10% and 15%) caused a significant decrease in the raw ash rate. As a matter of fact, in studies, many researchers have found that when they add molasses to plant silage, it reduces the raw ash rate compared to the control (Şahin, 2019; Gül, 2023). When molasses + wheat bran were used together, crude ash rates were found to be between 14.46-19.96%. All of these values had lower raw ash contents compared to the control quinoa silage without additives.

NDF Rate (%)

The NDF rate in quinoa silage without additives was determined as 26.20%. In the studies carried out by Podkòwka et al. (2018), Fang et al. (2022) and Güner and Temel (2022) found silage NDF rates of 45.31%, 29.10% and 37.02%, respectively. However, the NDF values determined in the current study were lower than previous studies. When wheat bran additive was used, NDF rates were found to be between 33.13%-34.53%. Wheat bran additive significantly increased the NDF rate of quinoa silage. As a matter of fact, in studies conducted on different plant silages, many researchers have found that the NDF rate is higher than the control group when they use wheat bran, broken wheat and cracked barley as additives (Kordi and Naserian 2012, Gülümser et al. 2019). When molasses additive was used, NDF rates were found to be between 22.86-28.23%. While the addition of 5% molasses did not cause a significant change in the NDF rate, it was determined that the addition of molasses at high rates (10% and 15%) caused a significant decrease in the NDF rate compared to the control silage. As a matter of fact, in studies conducted on silages of some plants, many researchers have found that when they use molasses as an additive, the NDF rate decreases compared to the control group (Bolakar and Yüksel, 2021; Gül, 2023). On the other hand, some studies reported that the addition of molasses caused an increase in the NDF rate (Gülümser et al., 2016; Fang et al., 2022). When molasses + wheat bran were used together, the NDF contents of quinoa silage varied between 26.03% and 30.40%. The lowest NDF rate was obtained when 15% molasses and 5% wheat bran additives were used together.

Table 2. Effects of molasses (M) and wheat bran (WB) additives on nutrients and organic acids of quinoa silage

Application	NDF (%)	ADF (%)	RFV	Lactic acid (%)	Acetic acid (%)	Propionic acid (%)	Butyric acid (%)
Control	26.20 d-f	17.46 de	268.20 bc	2.94 h	15.33 a	0.14 ı	0.013 b
5% WB	33.13 ab	19.83 ab	206.63 ef	5.64 g	12.84 b	0.27 h	0.724 a
10% WB	33.83 a	19.50 a-c	202.93 ef	9.90 f	3.44 c	0.28 h	0.026 b
15% WB	34.53 a	20.56 a	196.43 f	9.68 f	3.34 cd	0.43 g	0.034 b
5% M	28.23 c-e	17.26 de	250.50 b-d	14.22 c	2.78 c-e	0.52 f	0.015 b
10% M	24.90 fg	18.16 b-e	280.46 b	14.37 c	2.61 de	0.82 d	0.033 b
15% M	22.86 g	17.26 de	307.86 a	18.00 a	2.68 c-e	1.52 a	0.018 b
5% M x 5% WB	28.23 c-e	17.86 c-e	247.56 cd	11.16 ef	2.50 e	0.56 f	0.027 b
5% M x 10% WB	30.40 bc	18.56 b-d	227.80 de	10.16 f	2.30 e	0.54 f	0.026 b
5% M x 15% WB	27.96 c-f	17.70 de	252.76 b-d	11.05 ef	2.40 e	0.71 e	0.034 b
10% M x 5% WB	29.46 cd	16.70 ef	239.73 cd	14.23 c	2.69 c-e	0.81 d	0.029 b
10% M x 10% WB	28.73 c-e	14.96 g	249.86 cd	13.74 cd	2.69 c-e	1.04 c	0.025 b
10% M x 15% WB	29.30 c-e	15.46 fg	244.43 cd	12.13 de	2.06 e	1.16 b	0.019 b
15% M x 5% WB	26.03 ef	17.76 c-e	268.43 bc	16.14 b	2.41 e	1.19 b	0.030 b
15% M x 10% WB	28.30 c-e	18.16 b-e	245.53 cd	13.34 cd	2.19 e	1.12 bc	0.038 b
15% M x 15% WB	28.73 c-e	17.26 de	244.36 cd	13.48 cd	2.18 e	1.17 b	0.034 b
F value and significance	10.1**	7.2**	9.4**	38.9**	282.9**	212.0**	352.3**

**P<0.01[a,b,c] Means within a row with different letters differ by Duncan test.

ADF Rate (%)

In the control application of quinoa silage, ADF rates were determined as 17.46%. Silage ADF value was determined by Podkòwka et al. (2018), Fang et al. (2022), Güner and Temel (2022) found it to be 34.24%, 20.50% and 24.40% lower, respectively, while Güner and Temel (2022) found it to be 17.60%, close to the values in the current study. When wheat bran additive was used, ADF rates were found to be between 19.50%-20.56%. Wheat bran caused an increase in the ADF rate of quinoa silage. As a matter of fact, some studies have stated that ADF rates increased compared to the control when wheat bran, wheat cracked and barley crushed additives were used in plant silages (Çiftçi et al. , 2005; Kordi and Naserian, 2012; Gülümser et al., 2019). When molasses additive was used, ADF rates were found to be between 17.26-18.16%. The lowest value of the ADF rate was detected in the M 5% x WB 0% and M 15% x WB 0% groups (17.26%). Molasses addition did not cause a significant change in the ADF content of quinoa silage. Some studies have found that when molasses additives are used in silage plants, ADF rates decrease compared to the control group (Şahin, 2019; Bolakar and Yüksel, 2021). Some studies have found that when molasses additive is used in silages, it increases ADF rates compared to the control (Gülümser et al., 2019; Fang et al., 2022). When molasses + wheat bran additives were used together, ADF rates were found between 14.96-18.56%. The lowest ADF rate (14.96%) was obtained when 10% molasses and 10% wheat bran were applied together as additives.

Relative Feed Value

The relative feed value of quinoa control silage was determined as 268.20. Dumlu Gül et al. (2015), Acar and Bostan (2016), Canbolat et al. (2019), Bolakar and Yüksel (2021) and Gül (2023) determined the relative feed value of quinoa silage as 132.10, 143.19, 155.52, 61.53 and 92.78, respectively. When wheat bran additive was used in quinoa silage, relative feed values were found between 196.43-206.63. The highest relative feed value was determined in the 5% wheat bran application, and the lowest was determined in the 15% wheat bran application. The addition of wheat bran reduced the RFV value of silage. As a matter of fact, in studies conducted on different plant silages, many researchers found that when they used wheat bran, cracked barley and barley paste as additives, RFV was lower than the control group (Dumlu Gül et al., 2015; Acar and Bostan, 2016; Gül, 2023). In case of using molasses additive, relative feed values were found between 250.50-307.86. While 5% molasses application did not cause a significant change in the RFV value compared to the control silage, increased molasses application caused the RFV value to increase. It has been reported that molasses addition increases the RFV value of silage (Dumlu Gül et al., 2015; Acar and Bostan, 2016; Canbolat et al., 2019, Bolakar and Yüksel, 2021; Gül, 2023). When molasses + wheat bran were used together, the RFV values of silage were found to be between 227.80-268.43. In all combinations of molasses + wheat bran application, RFV value was lower than the control. This may be due to the fact that molasses increases the RFV value and wheat bran decreases the RFV value.

Lactic Acid Rate (%)

Lactic acid rates in quinoa silage were determined as 2.94 in the control group. While the lactic acid values of quinoa silage were found to be high in some studies based on the values obtained in the current study (Podkòwka et al., 2018; Güner and Temel, 2022), in some other studies the lactic acid values were found to be low (Salama et al., 2021; Yacout et al., 2021; Fang et al., 2022). When wheat bran additive was used in quinoa silage, lactic acid rates were found to be between 5.64-9.90%. The addition of wheat bran caused a significant increase in lactic acid content. Application of wheat bran more than 10% did not provide an additional increase in lactic acid content. For this reason, it has been determined that the application of more than 10% of wheat bran is unnecessary. In studies conducted on different plant silages, many researchers have found that when they use wheat bran and barley paste as additives, there are increases in the lactic acid rate compared to the control group (Qin and Shen, 2013; Acar and Bostan, 2016; Gül, 2023). When molasses additive was used, lactic acid rates were found between 14.22-18.00%. The addition of molasses provided a significant increase in the lactic acid content. This increase was greater than the addition of wheat bran. In studies, many researchers have found that when they add molasses to plant silage, the lactic acid rate increases compared to the control (Acar and Bostan, 2016; Canbolat et al., 2019; Fang et al., 2022). It is estimated that the use of easily soluble carbohydrate content of molasses by silage microorganisms causes the increase in lactic acid content. When mixtures of molasses + wheat bran in different proportions were added to quinoa silage, lactic acid rates were found to be between 10.16-16.14%. Lactic acid rates were found to be higher in all molasses + wheat bran mixture rates compared to the control silage. The highest lactic acid rate was obtained in the application of 15% molasses + 5% wheat bran.

Acetic Acid Rate (%)

Acetic acid rates in quinoa silage were determined as 15.33% in the control group. Podkòwka et al. (2018), Salama et al. (2021), Yacout et al. (2021), Fang et al. (2022) and Güner and Temel (2022) found acetic acid values of 0.37%, 3.06%, 3.06%, 7.08%, 8.54%, respectively, and they were found to be higher than the values obtained in the current study. When wheat bran additive was used in quinoa silage, acetic acid levels were found to be between 3.34-12.84%. It was determined that 5% wheat bran was not sufficient to reduce the acetic acid rate in quinoa silage, and the addition of 10% wheat bran was appropriate to reduce the acetic acid rate. Application of wheat bran more than 10% did not provide an additional reduction in acetic acid. In studies conducted by some researchers, they found that adding wheat bran to silages reduced the acetic acid rate compared to the control group (Qin and Shen, 2013; Silva et al., 2014). When molasses additive was used, acetic acid rates were found to be between 2.61-2.78%. The addition of molasses to quinoa silage caused a significant decrease in the acetic acid content. The addition of high amounts of molasses did not cause an additional increase in the acetic acid content. For this reason, it was determined that the addition of 5% molasses was sufficient to reduce the acetic acid content. Some studies have reported that using molasses additives in silages causes a decrease in the acetic acid rate (Canbolat et al., 2019; Fang et al., 2022). When molasses + wheat bran additives were used together at different rates, acetic acid rates were found to be between 2.06-2.69%. Compared to the control silage, the acetic acid rates obtained in all molasses + wheat bran applications mixed in different proportions were lower.

Propionic Acid Rate (%)

Propionic acid rates in quinoa silage were determined as 0.14% in the control group. In some studies, the propionic acid rates of quinoa silage were found to be lower (Fang et al., 2022; Güner and Temel, 2022). Compared to the control silage, the use of wheat bran and molasses additives increased the propionic acid rates. The largest increase rate was detected in the 15% molasses application. A study reported that adding molasses to forage pea silage increased the propionic acid content (Canbolat et al., 2019).

Butyric Acid Rate (%)

Butyric acid content in the control silage of quinoa was determined as 0.013%. In some studies, butyric acid rates of quinoa silage were found to be lower (Salama et al., 2021; Yacout et al., 2021; Fang et al., 2022; Güner and Temel, 2022). The addition of molasses, wheat bran and mixtures of both at different rates (except 5% wheat bran) to quinoa silage did not cause a significant change in the butyric acid rate compared to the control silage.

CONCLUSION

Molasses was used as an additive to increase the carbohydrate content in quinoa plant silage, and wheat bran additive was used to increase the dry matter content. Molasses used as an additive increased the dry matter, ADF, RFV, lactic acid, butyric acid and propionic acid values compared to the control group; It has also been found to reduce pH, ammonia, NDF, crude ash, crude protein and acetic acid values. It was determined that wheat bran as an additive increased the dry matter, crude protein, ADF, NDF, lactic acid and propionic acid values in quinoa silage, and decreased the pH, ammonia, RFV, crude ash, acetic acid and butyric acid values. It has been determined that molasses + wheat bran as an additive increases the dry matter, lactic acid, propionic acid, NDF and butyric acid values in quinoa silage, while it decreases the pH, crude protein, ammonia, ADF, crude ash, acetic acid and RFV values. When the research data were examined, molasses used as an additive in quinoa plant silage contributed to the increase in the carbohydrate content of the silage, resulting in the improvement of silage quality. On the other hand, it has been determined that the addition of wheat bran increases the dry matter level. It was concluded that adding 5% molasses and 15% wheat bran into the quinoa silage would be sufficient to obtain good quality quinoa silage.

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