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Investigation the Effects of Bacterial Additive and Moisture Absorbent on the Fermentability and Nutrient Composition of Potato Silage

Research Article

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ABSTRACT

Potato dry matter is mainly composed of starch, which can be used in animal feed due to its high available energy. This study aimed to improve the quality of potato silage using wheat straw and additives containing *Lactobacillus*. This study was conducted in a completely randomized design with 4 treatments and 3 replications: 1- Potatoes without additives, control, (PS), 2- Potatoes mixed with wheat straw (90:10 ratio on a fresh basis) (PWS), 3- Potatoes inoculated with SiloOne additive (including *Lactobacillus buchneri*, *Lactobacillus plantarium*, *Enterococcus faecium*, *Lactobacillus acidophilus*, *Lactic acid pediococcus* and multivalent enzyme), (PLS), 4- Sliced potatoes with wheat straw (90:10 ratio on a fresh basis) and SiloOne additive (PWLS). The samples were stored in laboratory silos for 60 days at a temperature of 25 degrees Celsius. According to the results, there was a significant difference between the treatments in terms of pH, dry matter (DM), ash and insoluble fiber in neutral and acidic detergents. The addition of wheat straw reduced the loss caused by silage effluent and increased dry matter (DM) recovery ($P<0.01$). The lactic acid concentration of inoculated silages (PLS and PWLS) was greater than non-inoculated silages ($P<0.01$). The lowest concentrations of acetic acid and propionic acid were observed in the treatment with wheat straw in the absence of lactic acid bacteria (LAB) (PWS) ($P<0.05$). Concentrations of valeric acid and iso-valeric acid were not affected by wheat straw and inoculation with LAB ($P>0.05$). The results of this study showed that ensiling potatoes with a wheat straw reduces silage effluent losses and increases DM recovery. But the fermentation quality and aerobic stability of PWS were lower than PS. However, LAB inoculation improved the fermentation quality. The use of wheat straw along with LAB inoculation increased the ratio of lactic acid to total volatile fatty acids (VFA).

KEY WORDS aerobic stability, bacterial inoculant, dry matter recovery, lactic acid, starch.

INTRODUCTION

Potato with the scientific name of *Solanum tuberosom* is an annual plant of the *Solanaceae* family (Pazhouhandeh *et al.* 2017) and one of the most important crops in the world after wheat and rice (Wang *et al.* 2022). Potatoes are used for human consumption and are not grown as animal feed, but every year part of the potato crop is lost due to overproduction and also as waste, which causes damage to farmers and environmental pollution. Iran is one of the top 20 potato-producing countries with a production of about 4.5 million tons of potatoes per annum (FAOSTAT, 2020). Potatoes are a rich source of starch, which usually makes up 25 to 90% (Barrell *et al.* 2013). Potato starch has larger granules compared to cereal starch and usually has an average diameter of 20 to 40 microns (Peshin, 2001). This property makes this material highly gelatinous and swells at a lower temperature. When potato starch granules become gelatinous, they swell significantly and break as a result. Cereal granules also swell, but do not reach the rupture stage (McDonald *et al*. 2010). Yusupha *et al*. (2003) reported that potato starch amylose levels were about 29.0% and the amylose to amylopectin ratio was 1: 2.42 on average, indicating high levels of amylose. Amylose is difficult to degrade and its molecular shape makes it difficult to gelatinize starch (Da Silva Figueiró *et al*. 2022).

During the peak production season, farmers are faced with the problem of disposing of surplus potatoes. Every year, part of the potato crop is wasted due to traditional harvesting in the fields, lack of cold storage and non-standard storage (Pringojin *et al*. 2005). For this reason, part of the annual potato production is no longer suitable for human consumption and part of it can be used as feed for livestock (Bradshaw *et al*. 2002). Its use in livestock is limited due to its high humidity. One of the ways that farmers can be suggested in high-yield seasons is to either silage the surplus potato crop alone or to silage it with one of the forage types. The most important factor in ensuring the success of fermentation is that the potato is not mixed with the soil during ensiling and its green buds are separated from it due to the high solanine content (Halliday, 2015).

Due to the seasonal production and low shelf life of potatoes, the need to use processes that enable us to provide this product all year round seems necessary. Forage storage in the form of silage is a common method of providing ruminant feed sources at times of the year when fresh forage is not available. In this method, due to the activity of lactic acid-producing bacteria and under anaerobic conditions, water-soluble carbohydrates in forage water are converted to organic acids (mainly lactic acid) and reduce the pH and thus protect forage from microbial spoilage (Filya, 2003).

Ensiling plant products with high humidity by losing large amounts of digestible nutrients through leakage reduces the nutritional value of silage for livestock, and the effluent from it can also cause environmental pollution (Zhang *et al*. 2012). Therefore, adding moisture absorbent materials such as wheat straw to potato silos can prevent the loss of nutrients in the silage effluent. Since potatoes must be washed before ensiling, the population of Lactobacillus in it is reduced, which to provide a sufficient population of LAB, it is necessary to add microbial additives containing these microorganisms to the shredded potatoes during silage. By using bacterial additives containing several strains of homogeneous bacteria, the actual synergistic activity between different strains can be used. Microbial additives from selected species of homogeneous lactic acid-producing bacteria such as *Lactobacillus plantarum*, *Pediococcus* and *Enterococcus* are good choices. Because several organisms differ in terms of growth rate, fermentation products and optimal growth conditions are used in the additive (Khorvash *et al*. 2014). It is expected that the use of wheat straw and SiloOne microbial additive will improve the quality of silage by reducing effluent production, proper fermentation and increasing the rate of pH drop.

MATERIALS AND METHODS

Silage preparation and treatment

The potatoes variety Agria was procured from the local market and transferred to the Khalatpooshan laboratory unit of Tabriz University. After washing the potatoes and ensuring that they were free from soil contamination, they were chopped into 2-3 cm pieces using a kitchen knife. Chopped potatoes allocated in four treatments including: 1- Potatoes without additives, control, (PS), 2- Potatoes mixed with wheat straw (90:10 ratio on a fresh basis), (PWS), 3- Potatoes inoculated with bacterial additive SiloOne, (Fidar Damdare Bartar Ariyayee company in Iran); contains *Lactobacillus buchneri*, *Lactobacillus plantarum*, *Enterococcus faecium*, *Lactobacillus acidophilus*, *Lactic acid pediococcus* and multivalent enzyme, (PLS) 4- Potatoes mixed with 10% wheat straw, which inoculated with bacterial additive SiloOne, (PWLS). The prepared mixture for each treatment was ensiled in three replications. For this purpose, laboratory silos were used, which included PVC pipes with a diameter of 10 cm and a length of 56 cm. The capacity of these silos is about 5 kg, which has a drain valve to remove the leachate. The ingredients were thoroughly mixed by hand. The silos were gradually filled with potatoes, pounded and compressed at the same time, and finally, the silos were closed with metal clamps so that air does not penetrate into them. During the 60-day storage period, the silos were regularly weighed and the effluent produced was measured.

Chemical analyses

Starch, DM percentage, ash content and neutral detergent fiber (NDF) and acid detergent fiber (ADF) of potatoes were determined before ensiling. After 60 days, all silos were opened and evaluated and sampled. Sampling was performed from a depth of 10 cm of silos. For this purpose, three samples were taken from each replication. After decanting the silage extract, pH, ammonia nitrogen, soluble carbohydrates, lactic acid and VFAs were determined. Another sample was used to determine chemical composition (DM, raw ash, pectin, NDF and ADF) and the third sample was used to measure aerobic stability. Hemicellulose content was calculated by difference as:

Hemicellulose= NDF – ADF

Simultaneously, the apparent quality of silage was evaluated using odor, texture and color indices by sensory method (Kilic, 1986).

The pH value was measured using a pH meter (model CG 804-Germany). Flieg points were calculated using the pH and DM values of the silos at the end of the fermentation period with the following equation (Kilic, 1986):

Flieg points= 220 + (2×% DM−15) − 40 × pH

Flieg index scores; a silo was considered very bad when it had a score of less than 20. Poor quality with a score between 21 and 40; average with a score between 41 and 60; Being well with a score of 61 to 80 and being very well when it is between 81 and 100.

The DM content of the samples was determined using an oven for 72 hours at 55 ˚C (Van Soest *et al.* 1991). Crude ash was determined by incineration in an electric furnace (AOAC, 2005). The NDF and ADF were determined according to Van Soest *et al.* (1991). Potato starch was measured using a centrifuge method (Yusupha *et al.* 2003). Ammonia nitrogen and water-soluble carbohydrates were measured by spectrophotometry and volatile fatty acids and lactic acid were measured by the use of high performance lipid chromatography (HPLC) (Wang *et al.* 2021).

Aerobic stability

To measure the aerobic stability of silages, 1000 g of each silage mixture was placed in plastic buckets and covered with a two-layer Cheesecloth. The thermometer was placed in the middle of the bucket inside the silo mass and the silage and ambient temperature were measured every two hours. When the temperature of the silage reached 2 ˚C higher than the ambient temperature, the silages were considered as rotten and moldy silage (Nishino *et al.* 2003).

Statistical analyses

The obtained data were analyzed completely randomly with 4 treatments and 3 replications for each treatment using SAS statistical program (SAS, 2004) and Tukey test (at 5% level) was used to compare the means.

$$Y_{ij}= \mu + T_i + e_{ij}$$

Where:
Y_{ij}: general observation.
μ: overall mean.
T_i: effect of treatment.
e_{ij}: experimental error effect.

RESULTS AND DISCUSSION

The chemical composition of raw potatoes with or without wheat straw is reported in Table 1.

The results of chemical analysis showed that the addition of wheat straw increased the percentage of DM and ash, NDF and ADF of potatoes.

Table 1 Chemical composition of raw potatoes before ensiling (%DM)

Items	Fresh potato	Fresh potato + 10% wheat straw
DM	21.07±0.50	25.67±0.60
Ash	4.69±0.29	5.45±0.14
NDF	6.9±0.14	30.70±1.56
ADF	2.32±0.24	29.12±1.09
HC	4.58±0.58	1.58±0.69
Starch	87.63±1.63	77.13±1.27

DM: dry matter; NDF: neutral detergent fiber; ADF: acid detergent fiber and HC: hemicellulos.

As shown in Table 2, the addition of wheat straw to potato silage caused a significant increase in pH (P<0.01), so potato silage with wheat straw had the highest pH in the absence of SiloOne additive (PWS). Because adding wheat straw to potatoes decreased the concentration of lactic and acetic acids and increased the concentration of ammonia nitrogen and butyric acid compared to other treatments (Table 4).

Babaeinasab *et al.* (2015) used different additives in potato silage and observed that the potato-wheat straw silage mixture without any additives had the highest pH.

The addition of LAB to potato silage (PLS) caused a significant decrease in pH because it increased the lactic acid of potato silage (Table 4). Ash, NDF and ADF values were significantly greater for treatments containing wheat straw compared to the control group (PS) (P<0.01). Since the percentage of minerals, NDF and ADF in wheat straw are high, adding it to potato silage increases ash and cell wall. The level of DM in the treatments containing wheat straw without the addition of SiloOne (PWS) was reduced compared to the control group (P<0.01), which can be due to the high water holding capacity of wheat straw, which preserves the moisture content of silages containing wheat straw, while a significant part of the moisture in silages without wheat straw (PS, PLS) was lost in the form of effluents (Table 5).

The lower the pH and the higher the DM in the silage, the better the score will be in terms of the Flieg point. Among the treatments in terms of the Flieg point, the treatment containing microbial additive alone (PLS) along with the control treatment (PS) scored very well in terms of the flag index. The addition of wheat straw to potato silage significantly reduced Flieg point (P<0.01). Because high pH reduces Flieg point.

Starch is the main carbohydrate of potatoes (Xia *et al.* 2021). The initial content of starch in potatoes was reported to be 87/63% of DM (Table 1).

Table 2 The effect of wheat straw and SiloOne additive on the chemical properties of potato silage (% DM)

Items	Treatments				SEM	P-value
	PS	PWS	PLS	PWLS		
pH	4.91[c]	5.24[a]	4.74[d]	5.08[b]	0.038	0.0001
DM	36.46[a]	33.08[b]	35.51[a]	35.41[a]	0.507	0.0005
Ash (% DM)	2.21[b]	4.28[a]	2.27[b]	4.25[a]	0.083	0.0001
NDF (% DM)	1.00[b]	16.43[a]	1.63[b]	16.62[a]	0.832	0.0001
ADF (% DM)	0.37[c]	9.43[a]	0.32[d]	8.65[b]	0.362	0.0001
HC (% DM)	0.63[b]	7.01[a]	1.31[b]	7.97[a]	0.854	0.0001
Starch (% DM)	59.38	60.56	57.26	57.03	3.963	0.7805
Flieg points	81.51[a]	61.71[b]	86.64[a]	72.62[b]	1.214	0.0001

DM: dry matter; NDF: neutral detergent fiber; ADF: acid detergent fiber and HC: hemicellulos.
PS: potato silage; PWS: potato-wheat straw silage; PLS: potato-*Lactobacillus* silage and PWLS: potato-wheat straw-*Lactobacillus* silage.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 3 The effect of wheat straw and SiloOne additive on the appearance quality of potato silage

Items	Treatments				SEM	P-value
	PS	PWS	PLS	PWLS		
Color (5)	4.67	5.00	3.33	5.00	0.873	1.576
Smell (5)	1.67[bc]	3.00[ab]	1.33[c]	3.50[a]	0.512	0.0053
Structure (5)	2.67[b]	4.33[a]	3.33[ab]	4.33[a]	0.534	0.0292
Total score (15)	9.01[b]	12.33[a]	7.99[b]	12.83[a]	1.472	0.0188

PS: potato silage; PWS: potato-wheat straw silage; PLS: potato-*Lactobacillus* silage and PWLS: potato-wheat straw-*Lactobacillus* silage.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

There was no significant difference in the amount of starch among the treatments, although the loss of starch in inoculated silages (PWLS and PLS) was higher than that of non-inoculated silages, but this reduction was not significant (P>0.05). In similar studies, the starch content of cooked potatoes after 42 days of DM silage was 21% (Lindahl *et al.* 1946). This difference in starch losses in raw and cooked potato silage is because heat treatment with sufficient water causes gelatinization, which increases the sensitivity to starch decomposition (Svihus *et al.* 2005). Because potato starch contains long-chain amylopectin (Chung and Liu, 2010), it needs more energy to gelatinize (Jane *et al.* 1999).

In another study, the starch content of potato pulp decreased after 50 days of silage; potato pulp silo without Lactobacillus additive (control group) had the least starch degradation (Okine *et al.* 2005). Loss of potato starch at neutral or low pH is due to microbial function (Sauter *et al.* 1979).

However, due to the losses due to silo effluent, losses due to bacterial hydrolysis were not significant in this study. Most LAB could not use starch directly because starch, unlike fructans, is slightly soluble in cold water (Narita *et al.* 2004).

Also, compared to other starch sources, potato starch has the highest resistance to hydrolysis, because the size of large granules of potato starch makes it resistant to hydrolysis (Rocha *et al.* 2010).

Silage can be classified based on appearance and parameters such as color, odor and structure. Color is an important property that reflects the quality of the silage.

The color of raw potatoes was yellow after slicing, and 60 days after silage, we saw a uniform yellow color in high-quality silages. Light color (yellow) was considered the optimal condition of silages and darker colors (brown, black) indicated the unfavorable condition of silage (Table 3).

The smell of silage is another feature that can be sensory assessed. None of the silages smelled good, and basically the potato silage smelled bad. But in good quality silages, the special smell of lactic acid could be inhaled.

In this experiment, the appearance of the silages showed the optimal condition of the silages. Assessments based on silage color ranged from 5 to 1, including white or light yellow, brownish yellow, brown, dark brown, black, or charcoal. Assessments based on silage smell ranged from 5 to 1, respectively, including vinegar odor, an odorless, mild odor of vinegar and leftover potatoes, bad odor, and a very bad odor. Immortality based on structure and texture ranged from 5 to 1, respectively: hard, softer, viscous, moldy silage. Based on the available results, treatments containing wheat straw alone or with bacterial inoculation (PWLS) had the highest total score in the sensory evaluation by sensory method (P<0.05). The treatment containing microbial additive alone (PLS) had the lowest total score in terms of appearance.

Table 4 The effect of wheat straw and SiloOne additive on the fermentation characteristics of potato silage

Items	Treatments				SEM	P-value
	PS	PWS	PLS	PWLS		
NH_3-N (mmol/100 mol)	5.80	5.64	4.71	5.45	0.620	0.2354
WSC (mmol/100 mol)	1.04	0.92	0.91	1.04	0.065	0.0755
Lactic Acid (mmol/100 mol)	37.17[a]	23.48[b]	39.95[a]	39.98[a]	1.364	0.0007
AA (mmol/100 mol)	47.41[bc]	43.89[d]	44.50[cd]	48.55[a]	0.757	0.0091
PA (mmol/100 mol)	10.91[a]	4.73[b]	8.69[a]	5.37[ab]	1.494	0.0402
BA (mmol/100 mol)	1.94[b]	24.47[a]	4.40[b]	3.5.8[b]	0.965	0.0001
VA (mmol/100 mol)	1.31	1.71	1.62	0.81	0.371	0.2079
IVA (mmol/100 mol)	1.25	1.71	1.64	0.88	0.309	0.1507
AA:LA	0.78[ab]	0.53[b]	0.91[a]	0.82[a]	0.039	0.0032
LA:VFA	0.59[a]	0.31[b]	0.66[a]	0.67[a]	0.035	0.0014

NH_3-N: ammonia nitrogen; WSC: water soluble carbohydrates; AA: acetic acid; PA: propionic acid; BA: butyric acid; VA: valeric acid; IVA: iso valeric acid and VFA: volatile fatty acids.
PS: potato silage; PWS: potato-wheat straw silage; PLS: potato-*Lactobacillus* silage and PWLS: potato-wheat straw-*Lactobacillus* silage.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 5 The effect of wheat straw and SiloOne additive on the dry matter recovery and nutrient wastage of potato silage

Items[1]	Treatments[2]				SEM	P-value
	PS	PWS	PLS	PWLS		
Silo effluent	41.84[a]	17.88[b]	38.28[a]	15.5[b]	2.231	0.0001
Oxidative loss	14.72[a]	4.31[b]	16.61[a]	3.72[b]	1.673	0.0001
DM recovery	43.33[b]	77.8[a]	45.12[b]	80.78[a]	1.666	0.0001

[1] DM is expressed as g/kg of as-fed diet, and all other items are expressed as g/kg DM.
PS: potato silage; PWS: potato-wheat straw silage; PLS: potato-*Lactobacillus* silage and PWLS: potato-wheat straw-*Lactobacillus* silage.
DM recovery: dry matter recovery.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 6 The effect of wheat straw and SiloOne additive on aerobic stability of potato silage

Items	Treatments				SEM	P-value
	PS	PWS	PLS	PWLS		
Aerobic Stability (h)	179.33[a]	78.67[b]	88.00[b]	81.00[b]	3.069	0.0001
Aerobic loose (%)	6.98[b]	7.46[b]	6.51[b]	11.06[a]	0.482	0.0001

PS: potato silage; PWS: potato-wheat straw silage; PLS: potato-*Lactobacillus* silage and PWLS: potato-wheat straw-*Lactobacillus* silage.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Fermentation properties of silos were affected by additives after 60 days, the results are reported in Table 4.

No significant difference was observed in terms of ammonia nitrogen among the treatments, although the treatment containing the microbial additive without wheat straw (PLS) had the lowest concentration of ammonia nitrogen. Because the PLS treatment had the lowest pH (Table 2). Low pH in the early stages of silage can inhibit the protease activity of plant enzymes and bacteria (Driehuis and Wikselaar, 1999) Lower ammonia nitrogen values indicate better silage quality. Because ammonia nitrogen production is related to CP degradation of silage, which reveals the extent of proteolysis in silage (McDonald *et al.* 1991). High pH in the control treatment and treatments containing wheat straw alone (PWS) or inoculated (PWLS) provided suitable conditions for protease activity of plant enzymes and bacteria, which increased the level of ammonia nitrogen in these silages.

Water-soluble carbohydrates (WSC) is the essential substrate for the growth of lactic acid-producing bacteria (LAB) in the fermentation process. Potato silage contains few WSC, which led to poor silage fermentation (Table 4). Because silo effluents contain WSC, they usually result in the loss of large amounts of digestible nutrients through leaching (McDonald *et al.* 1991). WSC is best used by lactic acid bacteria (LAB) in inoculated silage (Nkosi *et al.* 2010).

The concentration of lactic acid in inoculated silages (PWLS and PLS) was greater than in non-inoculated silages (PWS) (P<0.01). The amount of lactic acid produced was not enough to reach the desired pH in the PWS (Table 2). Because the pH of the silage increases with decreasing lactate (Borreani *et al.* 2018). Adding LAB to PWS increased lactic and acetic acid concentrations and decreased butyric acid concentrations (P<0.05). Potato starch contains higher amounts of long-chain amylose and amylopectin, resulting in a higher crystalline region with less hydrolysis (Wang *et al*. 2022). On the other hand, high pH during silage reduces the production of lactic acid from starch because high pH reduces acid hydrolysis and shorter chains, the crystal structure is not reduced and digestibility is reduced (Lee *et al.* 2018).

Some species produce Lactobacillus, amylase extracellularly and ferment starch directly to lactic acid. The amylolytic activity of the fermenting organism is a key feature of the fermentation of starch to lactic acid (Reddy *et al.* 2008). However, the amylolytic activity of microorganisms has less effect on the removal of starch that decomposes slowly (Monteils *et al*. 2002). WSCs are essential resources for LAB growth in the fermentation process (McDonald *et al*. 1991). High silage effluents (Table 5) reduce these resources because nutrients such as soluble sugars decompose faster than low-nutrient materials such as lignin, hemicellulose, and cellulose (Savoie and Jofriet, 2003) resulting in lactic acid production Being reduced. Adding wheat straw to potato silage (PWS) caused a significant decrease in propionic acid (P<0.05). The addition of LAB to PWS caused a significant increase in propionic acid (P<0.05). The concentration of butyric acid increased under the influence of wheat straw (P<0.01). Because high humidity and pH in PWS stimulate the growth of clostridium (Table 2). A large population of clostridial bacteria prevails instead of LAB if the forage is ensiled with a humidity of more than 70% (Savoie and Jofriet, 2003). Clostridium present in silage converts lactic acid and sugars into butyric acid. Concentrations of valeric acid and iso-valeric acid were not affected by wheat straw and microbial inoculation (P>0.05). Microbial inoculation of silage material increased the ratio of lactic acid to acetic acid (P<0.05). Numerous studies have shown the effect of LAB inoculation on increasing the lactic/acetic acid ratio in high moisture silage (Fang *et al*. 2022; Gallo *et al*. 2022).

The results of DM recovery of silage after 60 days are reported in Table 5.

Starch swelling is due to the ability of starch to trap and retain water in its structure (Damodaran *et al*. 2018). Absorption of more than 50% by weight of water by potato starch causes its reversible swelling (Nelson, 2010). The results of the research of Kaur *et al*. (2002) show that the higher swelling of potato starch can be due to its larger grains. It has also been suggested that the higher inflation rate of potato starch may be due to the higher content of phosphate groups in amylopectin because repulsion between phosphate groups in adjacent chains can increase hydration by weakening the bond in the crystal domain (Galliard and Bowler, 1987). It seems that slicing potatoes by releasing the structure of starch grains causes the release of water during the silage and thus increases the synergy of potato starch. Silage effluents contain sugars, soluble nitrogen compounds, minerals, and fermentable acids, all of which have high nutritional value (McDonald *et al*. 2010). The addition of wheat straw as a moisture absorber to potato silages largely prevented the loss of silage fluid during silage (Table 5). Effluent loss and oxidative loss were significantly affected by wheat straw, so effluent loss and oxidative loss in wheat straw treatments (PWLS and PWS) were significantly reduced (P<0.01). Because straw has a high cell wall with air cavities in its underlying matrix, water is replaced in this empty space (Dehghan *et al*. 2012). The difference between silage weight on the first day and silage weight at the end of the silage period as DM recovery as weight percentage was expressed in Table 4. The results showed that the lowest rate of DM reduction was in silages containing wheat straw (P<0.01), because straw has higher levels of NDF, adding it to potatoes increases NDF levels during ensiling (Table 1). Because nutrients such as soluble sugars are broken down faster than low-nutrients such as lignin, hemicellulose, and cellulose (Savoie and Jofriet, 2003), they are excreted in the effluent.

Aerobic stability values were significantly higher in control silos (PS) (P<0.01). The control treatments had the highest concentration of propionic acid (P<0.05) and high amounts of acetic acid (Table 4). Propionic acid and acetic acid act as fungicides and inhibit the growth of yeasts and molds, which increases aerobic stability in silage (Mohammadzadeh *et al*. 2013). In treatments with wheat straw and bacterial additive (PWLS) we had the highest weight loss during the aerobic stability measurement period (P<0.01).

CONCLUSION

Based on the obtained data, the use of wheat straw in potato silage decreased the production rate of silage effluent and increased DM recovery. However, the fermentation quality of PWS was lower than PS. Of course, bacterial inoculation of potato silage with straw (PWLS) increased the quality of silage fermentation with high moisture. In general, the use of wheat straw and LAB can improve the quality of potato silage.

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REFERENCES

AOAC. (2005). Official Methods of Analysis. 18th Ed. Association of Official Analytical Chemists, Gaithersburg, MD, USA.

Babaeinasab Y., Rouzbehan Y., Fazaeli H. and Rezaei J. (2015). Chemical composition, silage fermentation characteristics, and *in vitro* ruminal fermentation parameters of potato-wheat straw silage treated with molasses and lactic acid bacteria and corn silage. *J. Anim. Sci*. **93,** 4377-4386.

Barrell P.J., Meiyalaghan S., Jacobs J.M. and Conner A.J. (2013). Applications of biotechnology and genomics in potato improvement. *Plant Biotechnol. J*. **11(8),** 907-920.

Borreani G., Tabacco E., Schmidt R.J., Holmes B.J. and Muck R.E. (2018). *Silage review:* Factors affecting dry matter and quality losses in silages. *J. Dairy Sci*. **101(5),** 3952-3979.

Bradshaw L., MacGregor S. and Olsen T. (2002). Potato by-product feeding in the Pacific Northwest. *Vet. Clin. North Am. Food Anim. Pract*. **18(2),** 339-347.

Chung H.J. and Liu Q. (2010). Molecular structure and physicochemical properties of potato and bean starches as affected by gamma-irradiatio. *Int. J. Biol. Macromol.* **47(2),** 214-222.

Damodaran S., Parkin K.L. and Fennema O.R. (2018). Fennema's Food Chemistry. CRC Press, Boca Raton, Florida.

Da Silva Figueiró C., Trojaner M.R., Santana R.M.C. and Calcagno C.I.W. (2022). Rheological and structural characterization of cassava starches foam with low and high amylose contents. *J. Polym. Res*. **29,** 30-39.

Dehghan M., Tahmasebi R., Dayani O. and Kezre A. (2012). Determination of physical, chemical and digestibility of some agricultural by-products. *Iranian J. Anim. Sci. Res*. 3(4), 412-421.

Driehuis F. and Wikselaar V. (1999). The prevention of alcoholic fermentation in high dry matter grass silage. DLO Institut for Animal Science and Health, P.O. Box 65, 8200 AB, Lelystad, the Netherlands.

Fang D., Dong Z.,Wang D., Li B., Shi P., Yan J., Zhuang D., Shao T. and Wang W. (2022). Evaluating the fermentation quality and bacterial community of high-moisture whole-plant quinoa silage ensiled with different additives. *J. Appl. Microbiol*. **132(5),** 3578-3589.

FAOSTAT. (2017). Database of the Food and Agricultural Organization (FAO) of the United Nations. Availabe at: http://www.fao.org/faostat/en/#home.

Filya I. (2003). The effect of *Lactobacillus buchneri* and *Lactobacillus plantarum* on the fermentation, aerobic stability, and ruminal degradability of low dry matter corn and sorghum silages. *J. Dairy Sci*. **86,** 3575-3581.

Galliard T. and Bowler P. (1987). Morphology and composition of starch. Pp. 281 in Starch: Properties and Potential. T. Galliard, Ed. John Wiley and Sons, New York

Gallo A., Fancello F., Ghilardelli F., Zara S. and Spanghero M. (2022). Effects of several commercial or pure lactic acid bacteria inoculants on fermentation and mycotoxin levels in high-moisture corn silage. *Anim. Feed Sci. Technol*. **286,** 115256.

Halliday L. (2015). Ensiling potatoes. Prince Edward Island, Agriculture and Fisheries, Canada.

Jane J., Chen Y.Y., Lee L.F., McPherson A.E., Wong K.S., Radosavjevic M. and Kasemsuwan T. (1999). Effects of amylopectin branch chain length and amylose content on the gelatinization and pasting properties of starch. *Cereal Chem*. **76,** 629-637.

Kaur L., Singh N., Sodhi N.S. and Gujral H.S. (2002). Some properties of potatoes and their starches I. Cooking, textural and rheological properties of potatoes. *Food Chem*. **79(2),** 177-181.

Khorvash M., Mohammadzadeh H. and Yekdanegi M.B. (2014). Management of Silage Production and Utilization. Arkan Danesh Publications. Esfahan. Iran.

Kilic A. (1986). Silo Feed (Instruction, Education and Application Proposals). Bilgehan Press, Izmir, Turkey.

Lee S.Y., Lee K.Y. and Lee H.G. (2018). Effect of different pH conditions on the *in vitro* digestibility and physicochemical properties of citric acid-treated potato starch. *Int. J. Biol. Macromol*. **107,** 1235-1241.

Lindahl I., Davis R.E. and Ellis N.R. (1946). Effect of temperature and length of storage on ensilage made from cooked white potatoes. *J. Anim. Sci*. 5, 279-280.

McDonald P., Edwards R.A., Greenhalgh J.F.D., Morgan C.A., Sinclair L.A. and Wilkinson R.G. (2010). Animal Nutrition. Addison-Wesley Longman Ltd, London, United Kingdom.

McDonald P., Henderson N. and Heron S. (1991). The Biochemistry of Silage. Chalcombe Publications, Marlow, United Kingdom.

Mohammadzadeh H., Khorvash M. and Ghorbani G. (2013). Effects of bacterial inoculant containing homo and heterolactic lactobacillus on fermentation ofcorn silage and performances of Holstein dairy cattle. *J. Anim. Sci. Res*. **24(1),** 35-45.

Monteils V., Jurjanz S., Colin-Schoellen O., Blanchart G. and Laurent F. (2002). Kinetics of ruminal degradation of wheat and potato starches in total mixed rations. *J. Anim. Sci*. **80(1),** 235-241.

Narita J., Nakahara S., Fukuda H. and Kondo A. (2004). Efficient production of L-(+)-lactic acid from raw starch by Streptococcus bovis 148. *J. Biosci. Bioeng.* **97,** 423-425.

Nelson M.L. (2010). Utilization and application of wet potato processing coproducts for finishing cattle. *J. Anim. Sci*. **88,** 133-142.

Nishino N., Yoshida M., Shiota H. and Sakaguchi E. (2003). Accumulation of 1, 2 propanediol and enhancement of aerobic stability in whole crop maize silage inoculated with Lactobacillus buchneri. *J. Appl. Microbiol*. **94,** 800-807.

Nkosi B.D., Meeske R., van der Merwe H.J. and Groenewald I.B. (2010). Effects of homofermentative and heterofermentative bacterial silage inoculants on potato hash silage fermentation and digestibility in rams. *Anim. Feed Sci. Technol*. **157(3),** 195-200.

Okine A., Hanada M., Aibibula Y. and Okamoto M. (2005). Ensiling of potato pulp with or without bacterial inoculants and its effect on fermentation quality, nutrient composition and nutritive value. *Anim. Feed Sci. Technol*. **121(3),** 329-343.

Pazhouhandeh M., Karvan G. and Razavi A.S. (2017). A review on potato genetic engineering researches yet. *Genet. Eng. Biosaf.* **6(1),** 175-188.

Peshin A. (2001). Characterisation of starch isolated from potato tubers (*Solanum tuberosum*). *J. Food Sci. Technol. Mysore*. **38,** 447-454.

Pringojin I., Fallik E., Qat Y., Ajalin H., Allam M.M., Ezzat M., Al Masri M. and Bader M. (2005). Middle East Regional Agriculturel Program Survey on Postharvest Losses of Tomato

Fruit (*Lycopersicon esculentum*) and Table Grapes (Vitis Vinifera). Pp. 48 in Proc. 5th Int. Postharvest Symp. Verona, Italy.

Reddy G., Altaf M., Naveena B.J., Venkateshwar M. and Kumar E.V. (2008). Amylolytic bacterial lactic acid fermentation - a review. *Biotechnol. Adv*. **26,** 22-34.

Rocha T.D.S., Carneiro A.P.D.A. and Franco C.M.L. (2010). Effect of enzymatic hydrolysis on some physicochemical properties of root and tuber granular starches. *Ciênc. Tecnol. Aliment*. **30,** 544-551.

SAS Institute. (2004). SAS®/STAT Software, Release 9.4. SAS Institute, Inc., Cary, NC. USA.

Sauter E.A., Hinman D.D. and Howes A.D. (1979). Energy losses from potato processing waste during laboratory storage. *J. Anim. Sci*. **49,** 607-612.

Savoie P. and Jofriet J.C. (2003). Silage strorage. Pp. 405-467 in Silage Science and Technology. D.R. Buxton, R.E. Muck and H.J. Harrison, Eds. American Society of Agronomy, Madison, Wisconsin.

Svihus B., Uhlen A.K and Harstad O.M. (2005). Effect of starch granule structure, associated components and processing on nutritive value of cereal starch: A review. *Anim. Feed Sci. Technol*. **122,** 303-320.

Van Soest P.V., Robertson J.B. and Lewis B.A. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci*. **74(10),** 3583-3597.

Wang M., Wang H., Zheng H., Uhrin D., Richard J.D. and Rainer R. (2021). Comparison of HPLC and NMR for quantifcation of the main volatile fatty acids in rumen digesta. *Sci. Rep*. **11,** 24337-24345.

Wang L., Wang M., Zhou Y., Wu Y. and Ouyang J. (2022). Influence of ultrasound and microwave treatments on the structural and thermal properties of normal maize starch and potato starch: A comparative study. *Food Chem*. **377,** 131990.

Xia C., Zhong L,. Wang J., Zhang L., Chen X., Ji H., Ma S. Dong W., Ye X., Huang Y., Li Z. and Cui Z. (2021). Structural and digestion properties of potato starch modified using an efficient starch branching enzyme AqGBE. *Int. J. Biol. Macromol*. **184,** 551-557.

Yusupha M., Testera R.F., Ansella R. and Snapeb C.E. (2003). Composition and properties of starches extracted from tubers of different potato varieties grown under the same environmental conditions. *Food Chem*. **82,** 283-289.

Zhang W.W., Zhang Y.G. and Liu Z. (2012). Effect of different absorbents on fermentation quality of wet potato pulp. *J. Anim. Vet. Adv*. **22,** 4230-4235.