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The Effect of Dried Citrus Pulp, Dried Beet Sugar Pulp and Wheat Straw as Silage Additives on By-Products of Orange Silage

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Abstract: Silage of orange by-products (mainly the peel) is tested in micro-silos, carrying out and checking 4 treatments: addition of 5% (fresh weight) Dried Citrus Pulp (DCP), of dried sugar beet pulp (DSP), of Wheat Straw (WS) in 2 different times (0, 72 h). Silages were assessed using both method of appearance evaluation and method of DM, pH. CP, NDF, ADF, TVFA, WSC, aerobic stability and DM degradation each of treatments were determined after 60 days. Treated silages had better appearance quality than the control silages in Flieg's method. All of the silages had good and very good degrees in the method based on DM, pH. The treated silages had no differences pH compared with control. The control group that was sealed immediately, had lower DM content compared with treated silages ($p<0.05$). Treated silage with WS had the highest content of ADF ($p<0.05$). NDF in the control silage and the treated silage with DCP was lower than the others ($p<0.05$) and amount of CP in the treated silage with DSP was more than others ($p<0.05$). Time of ensiling and treatments made no difference in TVFA content of silages. WSC in treated silage with DCP and DSP were more than other samples ($p<0.05$). There are significant differences for the concentration of DDM, DE, ME, TDN in the silages. Treated silages with WS had lower contents than the others ($p<0.05$). The wilting before ensiling caused an increase in aerobic stability in treated silages compared with untreated silages ($p<0.05$). Application of WS additive resulted the lowest degradation dry matter among the experimental additives ($p<0.05$). Overall, in our experimental conditions, citrus pulp silage seemed to be convenient for producing animals.

Key words: Silage, by-products of orange, degradability, aerobic stability

INTRODUCTION

Increased disposal costs in many parts of the world have increased interest in utilization of citrus by-product feedstuff as alternative feeds for ruminants. The main citrus by-product feedstuff fed to ruminants are fresh citrus pulp, citrus silage, dried citrus pulp, citrus meal and fines, citrus molasses, citrus peel liquor and citrus activated sludge. Citrus by-product feedstuff can be used as a high energy feed in ruminant rations to support growth and lactation, with fewer negative effects on rumen fermentation than starch rich feeds (Leiva *et al*., 2000).

The main citrus by-product from citrus processing for juice are fresh citrus pulp which is the whole residue after extraction of juice, representing between 492 and 692 g kg^{-1} of fresh citrus fruit 600-650 g dry matter kg^{-1} peel, 300-350 g kg^{-1} pulp and 0-100 g kg^{-1} seeds (Ensminger *et al*., 1990). Citrus pulp is a valuable, high energy by-product that can partly replace cereal grains in sheep rations without adverse effect on milk yield or composition (Fegeros *et al*., 1995). Citrus fruits contain

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N (1-2 g kg^{-1} on a wet basis), lipid (oleic, linoleic, linolenic, palmitic, stearic acids, glycerol and a phytosterol), sugars (glucose, fructose, sucrose), acids (primarily citric and malic, but also tartaric, benzoic, oxalic and succinic), insoluble carbohydrates (cellulose, pectin), enzymes (pectinesterase, phosphatase, peroxidase), flavonoids (hesperidin, naringin), bitter principles (limonin, isolimonin), peel oil (d-limonene), volatile constituents (alcohols, aldehydes, ketones, esters, hydrocarbons, acids), pigments (carotenes, xanthophylls), vitamins (ascorbic acid, Vitamin B complex, carotenoids) and minerals (primarily calcium and potassium). The nutrient content of citrus by-product feedstuff is influenced by factors that include the source of the fruit and type of processing. A large number of the citrus by-product feedstuff is suitable for inclusion in ruminant diets because of the ability of ruminants to ferment high fiber feeds in the rumen (Grasser *et al*., 1995).

Volanis *et al*. (2004) reported that ensiled sliced oranges at 309 g kg^{-1} DM of the TMR was palatable to lactating dairy sheep, possibly due to its pleasant odour, while Migwi *et al*. (2001) suggested that the level of citrus pulp, ensiled with wheat straw and poultry litter, in the ration of sheep should be maintained between 150 and 200 g kg^{-1} DM to avoid depressed intake that may arise with higher citrus pulp levels, presumably due to low palatability. Conservation by ensilage has been practiced for many centuries. Ensilage is defined as the material produced by the controlled fermentation of a crop of high moisture or the preservation of a crop by natural fermentation under anaerobic conditions (McDonald *et al*., 1991). It is essential to have a good microbial fermentation process to produce high quality silage. A good fermentation process is not only dependent on the type and quality of the forage crop, but also on the harvesting and ensiling technique (Oude Elferink *et al*., 2000). Several factors directly or indirectly affect on the ensiling of high moisture by-product feedstuff. However, the high water content of citrus pulp is a major constraint in converting citrus pulp into a livestock feed. To solve this problem, the pulp could be made into silage. It contains high levels of Nitrogen-Free Extract (NFE), which can be a good substrate for fermentation. chemical changes during ensiling of orange peel and concluded that the initial high content of water, which is the result of processing to obtain the by-product feed stuff, affects the quality of the ensiled forage and makes a preparatory treatment of drying or moisture reduction necessary. Fermentative changes in organic acids and pH suggest that ensiling of orange peel causes lactic acid fermentation (Megias *et al*., 1993).

Citrus pulp may be ensiled alone or in combination with high DM cereal crop residues, such as wheat straw and poultry litter. The use of appropriate absorbent materials to ensiling is highly warranted in controlling effluent outputs from high moisture by-product silages (Migwi *et al*., 2001). It is more advantageous to mix the fresh pulp with partially dried grass or with legumes which cannot be successfully ensiled on their own. The liquid lost from the pulp will then be absorbed by the green fodder. Application of wheat straw in silage as an absorbent additive decreases ensiling losses but also decreases quality of silage (McDonald *et al*., 1991). This silage has a medium to high feeding value for sheep, provided that the level of citrus pulp in the ration is maintained between 150 and 200 g kg^{-1} DM to avoid depressed intake that may arise with higher citrus pulp levels. Increasing the level of citrus pulp in the silage resulted in a linear decrease in pH and a linear increase in titratable acidity of the silage after 60 days of fermentation. Silages made from mange fruit, lemon (at inclusion levels up to 200 g kg^{-1}), corn stover and molasses, with or without addition of urea, can also be utilized for feeding ruminants, with CP and NDF content with or without addition of urea (20 g kg^{-1}), being 214, 553, 65 and 644 g kg^{-1}, respectively, with an optimum fermentation time of 30 days (Aguilera *et al*., 1997). Due to high moisture content of citrus pulp, ensiling losses are high and can have a high impact on the farm environment. To avoid these problems, citrus pulp was ensiled together with chopped wheat straw which limits ensiling losses and gives to the silage the characteristics of a good and cheep substitute for farm forage. Citrus pulp and wheat straw silage seemed to be economically convenient for producing animals with substantially unmodified carcass and meat quality characteristics (Scerra *et al*., 2001).

Dried Citrus Pulp (DCP) is the main by-product from the citrus-processing industry that is used as a feedstuff for ruminants. The DCP is a mixture of peel, inside portions and culled fruits of the citrus family (e.g., orange, lemons and grapefruit) that has been dried to produce a coarse, flakey product. The nutrient content of DCP is influenced by several factors, including source of fruit and type of processing. The DCP is a pectin-rich bulky concentrate that is high in energy and low in CP and NDF, some properties are similar to roughage and promote relatively high ruminal pH. DCP contains relatively large amounts of pectin and soluble carbohydrates and very limited amounts of available N (Rihani *et al*., 1993).

Dried sugar beet pulp (DSP) and DCP utilize as the additives to silage high moisture forage mainly for decrease content of dry matter. DSP is the appropriate absorbent materials that decrease weakest water of silage and decrease quality of fermentation. DSP have extra sugar and it can be as an appropriate additive to increase lactic acid bacteria activity (McDonald *et al*., 1991).

One of the preservation methods of inhibiting growth of undesirable organisms is the wilting forage. Lactic acid bacteria can do fermentation activity in high DM forage but lack of moisture inhibited growth of clostridia, which caused excessive production of butyric acid. Clostridia are sensitive to moisture for their activity. The wilting forage before ensiling decrease exit of production of silage (McDonald *et al*., 1991).

MATERIALS AND METHODS

The experiment was carried out on what remained, mainly peel, after washing and extraction of segments of the fruit. This material was put in micro-silos by-products orange treated with nothing (control), or with 5% (wt/wt wet by-products orange) DCP, of DSP, of wheat straw (WS) and ensiled immediately in quadruplicate 10 L micro silos. Portions of the by-products orange, untreated and treated, were left in loose piles on a clean concrete floor in a barn for 72 h before being packed into silos. Empty and full weights of silos were recorded and silos were stored in the dark at ambient temperatures ranging between 18 and 25°C. All of the silos for each treatment were opened after 60 days of ensiling. The DM content of fresh by-products of orange and silage samples was determined by drying (70 to 75 g) in a forced-air oven at 60°C for 48 h. After drying, samples were ground. Ten gram samples of silage from each treatment were diluted 100 mL sterile deionized water and blended for 2 min. Silage pH determined immediately. ADF and Neutral detergent fiber was analyzed by using sulfite and amylase (Van Soest *et al*., 1991). Total nitrogen was determined after total combustion (LECO Corporation, CNS 2000 Analyzer; St. Joseph, MI) and CP was calculated by multiplying total nitrogen by 6.25. Starch was analyzed by using the method described by Poore *et al*. (1993). Fresh by-products orange silage (25 g) was added to a dilution bottle that contained 225 mL of sterile quarter-strength Ringer's solution (Oxoid BR54; Unipath, Basingstoke, UK) and homogenized in a blender for 1 min. After blending, water extracts were filtered through Whatman 54 filter paper (Whatman Inc., Clifton, NJ), acidified with 50% sulfuric acid and frozen before analysis of Water-Soluble Carbohydrates (WSC) (Nelson, 1944). The pH of silage extracts was determined within 20 min of homogenization. After 60 days of ensiling, when silos were opened, silage was mixed well and a 2 kg sample was returned to its respective silo. No physical packing of the silage took place. A thermometer was placed in the geometric center of each silage mass and temperatures were recorded every 3 h. A double layer of cheesecloth was placed on the top of each silo to prevent contamination but allowed for penetration of air because silos were incubated between 21 and 22°C. Aerobic stability was defined as the number of hours before a 2°C increase in temperature of the silage mass relative to ambient temperature. The temperature and pH of silages were recorded for 144 h, each 24 h once. For the determination of *in situ* ruminal DM, dry by-products orange silage samples were ground to pass through a 2 mm screen and 0.5 g of silage was weighed into Dacron bags (5×10 cm, 53 μm pore size; Ankom, Fairport, NY) (Van soest and Wine, 1967). Duplicate bags were placed in the rumen of a fistulated sheep fed a diet that was 82.4% alfalfa hay/grass hay, 8.8% soybean meal and 8.8% dry rolled barely. Bags were incubated for 0, 4, 8, 16, 24, 48 and 72 h. After removal from the sheep, bags were washed with water until effluent was clear and then were dried at 55°C for 48 h. Dried bags were weighed and DM disappearance was determined. The chemical composition of by-products orange and silages was analyzed as a factorial in a completely randomized design by the general linear models procedure of SAS/STAT (1996). Factors were ADF%, NDF%, CP%, WSC%, TVFA (Mmol kg^{-1}), DDM%, DE (Mcal kg^{-1}), ME (Mcal kg^{-1}), TDN%. Means were separated by Duncan test at 0.05 probability level (Duncan, 1955). The kinetics of ruminal DM disappearance *in situ* was estimated by the Naway software.

RESULTS

Appearance Evaluation

In this study, each of the factors including like to smell, color and structure (appearance characters) based on Flieg's score has given a number. Treated by-products orange silages with the additives had better appearance than others. Control group had lower appearance quality than the other treatments in all of sealing times.

In this evaluation method, the maximum of pH for stating in very good degree silage with 20-25% DM is 4.1-4.2. In the present study, average DM was 23% and pH ranged from 3.8 to 4.3, therefore all of silages were stated in good and very good class (Table 1).

Chemical Composition

The treated silages had no difference pH compared with control. The control group that was ensilaged immediately, had lower DM content compared with treated silages ($p<0.05$). Treated silages with WS had higher ADF than the others ($p<0.05$). In the control group and the silages which DCP had been added, content of NDF was lower than the other treatments ($p<0.05$). The amount of CP in the treated silage with DSP was more than others ($p<0.05$). The WSC concentration of treated silage with DCP and DSP were more than other samples ($p<0.05$). Delaying in sealing and treatments made no differences in TVFA content of silages. There are significant differences for the concentration of DDM, DE, ME, TDN in the silages and treated silages with WS had lower contents than the others ($p<0.05$) (Table 2).

In situ Ruminal DM Digestibility

Apparent *in situ* ruminal DM digestibility is presented in Table 3. Sealing time had no effect on *in situ* ruminal DM digestibility of silages. Addition of the additives to silages affected *in situ* ruminal DM digestibility of treated silages. So that, *in situ* ruminal DM digestion of silages with WS additive (345.6 g kg^{-1}) was lower than other treatments and control group, significantly ($p<0.05$). Sealing time had no effect on *in situ* ruminal DM digestibility of silages.

Table 1: Appearance evaluation based on dry matter and pH Flieg's method

Delaying time[1] (h)	Additive type[2]	DM (g kg^{-1})	pH	Judgment
0	Control	21.00[b]	3.95[a]	Good
0	DCP	23.28[a]	4.08[a]	Very good
0	DSP	22.98[a]	3.93[a]	Very good
0	WS	22.54[a]	4.30[a]	Good
72	Control	23.60[a]	3.94[a]	Very good
72	DCP	24.46[a]	3.80[a]	Very good
72	DSP	24.22[a]	3.87[a]	Very good
72	WS	24.70[a]	4.19[a]	Very good

[1]Delaying time of sealing = 0 h, 72 h. [2]Control = Without any additive. DCP = Dried citrus pulp, DSP = Dried sugar beet pulp, WS = Wheat Straw. Dissimilar superscript in the same column differ significantly ($p<0.05$)

Table 2: Chemical composition (DM based) by-products of orange silage after 60 days of ensiling (sealing time is fixed)

	Treatment[1]			
Items	Control	DCP	DSP	WS
Acid detergent fibre (g kg^{-1})	241.30[a]	226.10[a]	232.50[a]	362.70[b]
Neutral detergent fibre (g kg^{-1})	237.60[c]	240.20[c]	324.20[b]	408.10[a]
Crude protein (g kg^{-1})	51.70[ab]	56.30[ab]	98.10[a]	43.00[b]
Total volatile fatty acid (Mmol kg^{-1})	1976.00[a]	1824.20[a]	1741.90[a]	1664.90[a]
Digestible dry matter[2] (g kg^{-1})	701.00[a]	712.80[a]	707.80[a]	606.40[b]
Digestible energy[3] (Mcal kg^{-1})	3.02[a]	3.07[a]	3.04[a]	2.61[b]
Metabolizable energy[4] (Mcal kg^{-1})	2.48[a]	2.52[a]	2.49[a]	2.14[b]
Total digestible nutrition[5] (g kg^{-1})	684.90[a]	696.30[a]	689.40[a]	591.90[b]

[1]Control = Without any additive. DCP = Dried citrus pulp, DSP = Dried sugar beet pulp, WS = Wheat straw. [2]Digestable dry matter = 88.9-0.779 (ADF). [3]Digestable energy = 0.027+0.0427 (%DDM). [4]Metabolizable Energy = DE *0.821. [5]Total digestible nutrition = DE/0.04409 (Khalil *et al*., 1986). Dissimilar superscript in the same row differ significantly (p<0.05)

Table 3: Apparent *in situ* DM digestion of by-products of orange silage (sealing time is fixed)

	Treatment[1]				Delaying time of sealing[2]	
Items	Control	DCP	DSP	SW	0 h	72 h
DM digestion (g kg^{-1})	459.80[ab]	473.50[a]	482.20[a]	345.60[c]	468.70[a]	477.00[a]
Kd[3] % h^{-1}	5.10	5.80	5.90	6.10	5.10	5.40
SE	1.25	1.56	1.75	1.64	1.46	1.64

[1]Control = Without any additive. DCP = Dried citrus pulp, DSP = Dried sugar beet pulp, WS = Wheat straw. [2]Delaying time of sealing = 0 h, 72 h. [3]Kd = Rate of digestion. Dissimilar superscript in the same row differ significantly (p<0.05)

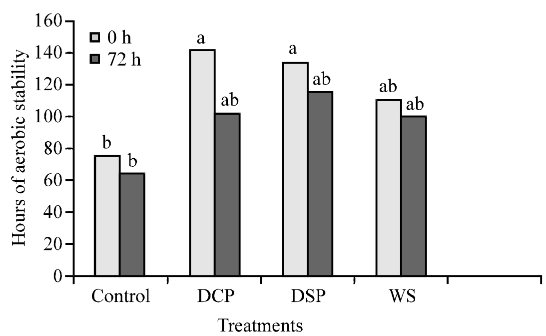

Fig. 1: The aerobic stability of By-products of orange silage, Control = Without any additive. DCP = Dried citrus pulp, DSP = Dried sugar beet pulp, WS = Wheat straw. Delaying time of sealing = 0 h, 72 h. SE = 10. [a,b,ab]Bars with unlike letters differ (p<0.05)

Aerobic Stability

Significant interactions between additive and sealing time were found for pH and temperature (p<0.05). Temperature of control silages in all sealing time after 76 h exposure to air 2°C increased and after 144 h received to own peak of temperature (immediately = 26.05°C, 72 h delaying = 24.80°C) (Fig. 1).

DISCUSSION

Appearance Evaluation

Applications of absorbent material additives improve quality of fermentation high moisture Silage (McDonald *et al*., 1991).

Chemical Composition

Observations about of DM showed that the control group that was ensilaged immediately had lower DM content. The reason for this finding related to the absorbing power of additives in this experiment. Wilting forage before sealing increase DM content of silage, too. Some studies showed that wilting forage before ensiling increase dry matter of silage (McDonald *et al*., 1991).

Treated silages with WS had higher ADF because wheat straw in silage as an absorbent additive decreases quality of silage (McDonald *et al*., 1991). One half of hemicellulose analysis during of fermentation silage, DCP is a stimulating fermentation additive because containing extra sugar that utilize by microorganisms as the nutrition matter and increase their fermentation activity (McDonald *et al*., 1991). So that, in this experiment, content of NDF in treated silage with DCP additive decreased.

DSP had the highest content of CP in the additives, in this study (NRC, 2001) therefore the treated silage with DSP had more CP than others. On the other hand, DSP such as DCP, is a stimulating fermentation and increase quality of fermentation silage. Additives containing carbohydrates result to decrease ammonia-N by stimulating fermentation and via this effect, it improves amount and quality of protein silage (McDonald *et al*., 1991).

In this experiment, WSC concentration of treated silage with DCP and DSP were more than others. Non structural carbohydrates are water soluble mainly and ferment in silage during the fermentation (McDonald *et al*., 1991). After fermentation remain very little water soluble carbohydrate, which has produced by enzyme activity and hemicellulose hydrolysis because lactic acid bacteria don't attack starch (McDonald *et al*., 1991). DCP contains relatively large amounts of pectin and soluble carbohydrates (Rihani *et al*., 1993).

Delaying in sealing and treatments made no differences in TVFA content of silages. The results of some studies detected that high moisture by-product fruits provide necessary energy for lactic acid bacteria to producing lactic acid. Usually in such silages, pH decrease, concentration of lactic acid increase and final quality of silages improve (Migwi *et al*., 2001).

In this study treated silages with WS had lower contents of DDM, DE, ME, TDN than the other treatments. Many of studies reported that addition wheat straw decreases quality of silage (McDonald *et al*., 1991).

***In situ* Ruminal DM Digestibility**

Starch based materials when available in large proportion and used as material for ensiling would influence the nutritive value if they survive the ensiling process, since they would be available to amylotic organisms in the rumen. In the present study *in situ* ruminal DM digestion of silages with WS additive was lower than other treatments and control group. This results show that WS decrease nutrition value of silage (McDonald *et al*., 1991). This study indicates that a lower water content of citrus pulp might affect both the *in vivo* production of organic acids and nutrient digestibility.

Aerobic Stability

Temperature and pH values of silages after opening explained that wilting by-products orange before ensiling, affected in inhibiting temperature raise of silage after exposuring to air. Experimental absorbent additives in all sealing time had positive effect on inhibiting of raising pH values of silages, which is similar to results of (Migwi *et al*., 2001).

CONCLUSIONS

When high moisture by-products orange is exposed to air for a period of time before ensiling and absorbent additives is added to them, resulted in increased dry matter content of silages. Exposure to air before ensiling also reduced *in situ* DM digestion, but not if silage was treated with a DSP and DCP regardless of timing of the application. These results show that use of DSP and DCP as absorbent additives can partially, but not totally, compensate for poor silo management practices. However, rapid filling of silos and achieving adequate packing densities to exclude excessive air should still be high priorities for making excellent quality silage.

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