



Fermentative characteristics and nutritional value of banana peel silage with carob syrup

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Abstract

The nutritional evaluation of banana peels and green cultured barley silages, supplemented with either 11% molasses or carob pod syrup, was conducted as part of this study. The results concluded that the physical characteristics of the silages were all within acceptable limits, classified as either good or very good silage quality. The quality score of the silages indicated that the highest quality was achieved with supplementation of carob pod syrup. In addition, the *in vitro* dry matter digestibility, organic matter digestibility, and the metabolizable energy value were significantly greater ($p < 0.01$) in the carob pod syrup than with the molasses supplementation. A significant difference ($p < 0.01$) was also found in dry matter digestibility, organic matter digestibility, and non-fibrous carbohydrate content, while the dry matter content did not show any difference. The addition of carob pod syrup to green cultured barley silage reduced fermentation losses; however, the silage's fiber and protein quality declined when supplemented with carob pod syrup. In terms of the chemical composition of the silages, *in vitro* dry matter digestibility, organic matter digestibility, and the metabolizable energy values were significantly higher ($p < 0.01$) in silage B (42.62%, 65.70%, and 6.39 MJ/kg DM, respectively) than in silage A (37.38%, 49.90%, and 5.61 MJ/kg DM, respectively).

Keywords:

Carob pod syrup, green cultured barley, banana peel, silage, in vitro digestibility.

INTRODUCTION

Using the ensiling method of temporary storage of feedstuff is a successful approach to decreasing feed limitations when feed resources are in short supply.

An effective method for storing fresh forage for an extended period of time is using silos (Hassan and Alsamari, 2016). Banana residues are not nutritionally balanced; however, with added supplements or treatment they can function as excellent ruminant feeds (Rusdy, 2019). Banana peel specifically represents a low-cost, viable feed option for livestock (Bin Jais et al., 2017). Dried banana peels can be added to grasses or grains used in silage, due in part to their high dry matter, high dietary fiber, and high carbohydrate (32.4%) content (10-21% pectin) (Mohapatra et al., 2010). Additionally banana peels have higher levels of minerals (e.g., potassium, sodium) than most forages (Anhwange et al., 2008) as well as PUFAs, EAA, and antioxidants (e.g.,

carotenoids, catecholamines, polyphenols) (Abu Bakar et al., 2018). The analysis of the amino acid profile shows all 10 EAA with lysine (7.28%), isoleucine (6.90%), leucine (5.94%) and threonine (5.87%) being the highest present (Angelis, 2025).

Cows consuming silage containing 60% replaced with dried banana peel did not result in decreased milk production with an average of 16.49 kg/d of milk with a 3.5% butterfat (Angelis, 2025) while lowering feed costs. Further, feeding 10-40% of the required roughage as dried banana peel in the diet increased ($P < 0.001$) DMD, OMD and VFA; and decreased ($P < 0.001$) the amount of NH_3 (Ramdani et al., 2019). Although grasses provide very good nutrients when used in silage production, the high moisture content of grasses can lead to poor quality after fermentation (Zanine et al., 2016). The level of dietary fiber in banana peel (approximately 50 g of dietary fiber/100 g banana peel) indicates that it is a very good source of dietary fiber (Emaga et al., 2007). The lignin levels in banana peel increase with ripeness of banana from 7% -15% (dry matter). On average, banana peel contains 6-9% protein and 20-30% dietary fiber (dry matter). Therefore, feed ingredients from banana peel provide all nutrients necessary for ruminants (Huzir et al., 2024).

The carob tree (*Ceratonia siliqua*), an evergreen plant. The unique aroma of the carob pod is produced from the isobutyric acid (1.3%) present in the pod. The carob pod also has a large quantity of tannins, which exert many favorable effects due to their biological properties. Tannins from the carob pod inhibit bacterial, yeast and fungal growth. The carob pod has a high fiber content (8%) and a high sugar content; mainly dextrose and starch (Khair et al., 2001). Thus, this study's purpose was to compare the fermentation characteristics and nutrient composition of silage from carob pod syrups and molasses as supplements.

Material and methods

Barley grain was sprouted in a still hydroponic growing chamber for 8 day periods and chopped into 5-8 cm length, carobs pods syrup prepare by 100 gm of dry ground carob boiling with 3 liter distilled water until became thicken, filtered and liquid part is taken, silages was prepared as follows :

A-50% dry banana peels, 34% green cultured barley, 16% of white corn, 11% molasses (M) .

B-50% dry banana peels, 34% of green cultured barley, 16% of white corn, 11% carobs pods syrup (CPS) .

Molasses and carobs pods syrup (cps) melted in 40% distilled water, filling and compress in duplicate polythene bags in order to minimize the risk of aerobic exposure, storage for 40 days. The chemical composition of fresh banana peel has shown in table 1 .

Assessing Quality of Silage

At the conclusion of 40 days of fermentation (storage), the bags were opened, and the physical quality was assessed based on characteristics viewed (mold and color, odor, and temperature, and the texture). Fermentation characteristics (e.g., the percentage of water extracted, the pH of the product, and quality classification) for each silage material were determined as outlined by Hassan (2014). Additionally, the Flieg point was calculated using the following equation as described in Denek et al. (2004): $\text{Flieg point} = 220 + (2 \times \% \text{ dry matter} - 15) - 40 \times \text{pH}$.

Chemical Composition

Chemical composition measurement results for silage samples included: (1) crude protein, crude fiber, ether extract, and ash content, which were analyzed per AOC's recommended method in 2023; (2) neutral detergent fiber (N.D.F.), acid detergent fiber (A.D.F.), and acid detergent lignin (A.D.L.) were analyzed by methods as cited by Van Soest et al. (1991); and (3) in vitro dry matter digestibility (I.V.D.M.D.) and in vitro organic matter digestibility (I.V.O.M.D.) were calculated by the equation reported by Tilley and Terry.(1963)

Statistical Analysis

Data for each of the experiments was analyzed using the SAS statistical analysis program, wherein differences among means were compared using Duncan's multiple range test.(1955)

Results and Discussion

Physical Characteristics

The physical characteristics of all four (4) silage samples varied in color from light greenish brown to greenish brown. According to Oduguwa et al. (2007), this color would indicate good fermentation and would be considered normal for grass silage. All four (4) silages had acceptable (pleasant) aromas ranging from very fruity to slightly fruity. There was moderate-to-firm texture associated with all silages and, therefore, the samples were considered to have a desirable texture, characteristic of well-preserved silages (Kung and Shaver, 2001). All silages were evaluated as having a temperature range of 27.5 to 28° C, which is consistent with normal fermentation. Increased temperatures could contribute to the Maillard reaction and, subsequently, decrease the digestibility of fibers and proteins (Bolsen et al., 1996). All silage materials had a complete lack of mold growth, suggesting that carob pod syrup (C.P.S.) improved fermentation quality of the silage material.

Fermentation Characteristics

The fermentation profile of the four (4) silage samples is reported in Table 3. As shown in Table 3, pH levels decreased from 4.8 to 4.5 with the addition of C.P.S. to the silage samples. The pH values for all silage samples analyzed in the study were within the acceptable range for high-quality silage located in the tropical climate region (Bilal, 2009). The percent of water extraction results from the silage prepared with carob (sample A) was 65.31%, while final percent of water extraction for silage prepared without carob (sample B) was 64.76%, which supports the previous conclusion that C.P.S. had a positive influence upon the quality of the silage. Flieg points for samples A and B were 76 and 89, respectively, indicating that samples A and B both had acceptable Flieg points and would thus support the conclusion that C.P.S. improved fermentation quality of both silages. Kara et al. (2009) reported Flieg points of 120.8 and pH 4.2 for triticale silage, which is difficult to compare due to the lower Flieg Points for the banana peel silage. Based on the pH values obtained from the banana peel silage utilized in the current study, the silages produced would be rated as acceptable for palatable silage. However, the Flieg Points for the banana peel samples were considerably lower. According to Alçiçek et al. (1999), sample A would be rated as good quality, while sample B received a very high quality rating.

Table 1. Chemical composition of fresh

Parameter	%banana peel
Dry matter	91.76
Organic matter	81.39
Ash	10.37
Ether extract	1.45
Nitrogen free Extract	72.68
Crude protein	15.50
NDF	42.08
ADF	29.48
Hemecellulose	12.60
Cellulose	19.87
Lignin	9.61

Table 2: Physical quality of the silages

Parameter	Silages	
	A	B
Color	light Greenish Brown	Greenish Brown
Odor	Pleasant with intense fruit smell	Pleasant with slight fruit smell
Texture	Moderately Firm	Moderately Firm
Temperature	28	27.5
Moldiness	Without Mould	Without Mould

A-green barley cultured 34%, white corn16%, dry banana peels 50% and molasses11%

B. green barley cultured 34%, white corn16%, dry banana peels 50% and carob syrup 11%

Table 3. Fermentation characteristics and Fleig points of the silages

Parameter	Silages	
	A	B
Water Extraction%	65.31	64.76
PH	4.8	4.5
*F.P.	76	89
Quality classify	Good	Very good

A-green barley cultured 34%, white corn16%, dry banana peels 50% and molasses11%

B. green barley cultured 34%, white corn16%, dry banana peels 50% and carob syrup 11%

*Fleig points = $220 + (2 \times \% \text{ dry matter} - 15) \cdot 40 \times \text{PH}$

Where Fleig Points: 81 -100 Very good , 61 . 80 Good, 40-60 Satisfactory, 21. 40 Middle, 0 - 20 Bad.

*81-100 scores; very good, 61-80 scores; good, 41-60 scores; satisfactory, 21-40 scores; middle, 0-20 scores; bad (Alçiçek et al., 1999)

Chemical Composition

The chemical composition of the silages is given in Table 4. It was noted that the in vitro digestibility of DM, OM and the metabolizable energy values were greatly enhanced ($P < 0.01$) for silage B (42.62, 65.70 and 6.39 MJ/kg DM) compared to silage A (37.38, 49.90 and 5.61 MJ/kg DM). The ether extract content of silage A was significantly greater ($P < 0.05$) (1.55%) compared to silage B. There were no significant differences in DM, DM recovery, OM, CP, ash, NDF, ADF, hemicellulose, cellulose or lignin for both silages. Chemical composition of silage provides a critical measure of the changes occurring during the ensiling process (Saeed and Muhamad, 2017) .

It can be concluded from these results that banana peels could be included in animal feed formulations as they contain large amounts of nutrients and minerals needed for the healthy development of livestock. In addition, using banana peels in this way can help the environmental problem of banana peel waste (Hassan et al., 2018) .

The increases in the in vitro digestibility of DM and OM may be due to an increase in the amount of soluble sugars leading to degradation of cell walls and creating an environment for the microbes to use nitrogen sources. In an experiment by Álvarez et al. (2015), they found that banana by-products had moderate levels of silage DM (20-30%) and OM (85-94%) but were low in Protein and Fiber. Other fruit coproducts such as: apple pomace, mango fruit waste, banana peels and citrus byproducts have nutritionally equivalent Protein and Energy values and should be used as feed for animals (Das et al., 2013).

Table 4. Chemical Composition (%) and estimated energy (MJ/Kg DM) of the silages

Parameter	Silages		
	A	B	
Dry matter	92.82	97.22	NS
Dry matter Recovery	31.65	32.27	NS
Organic matter	81.32	85.22	NS
Crude protein	19.31	19.84	NS
Ash	11.50	12.01	NS
Ether extract	1.55	5.30	*
IDMD%	37.38	42.62	**
IOMD%	49.90	65.70	**
ME (MJ/kg DM)	5.61	6.39	**
NDF	39.01	38.49	NS
ADF	28.30	28.42	NS
Hemecellulose	10.71	10.07	NS
Cellulose	18.59	18.60	NS
Lignine	9.71	9.82	NS

A-green barley cultured 34% , white corn16%, dry banana peels 50% and molasses11%

B- green barley cultured 34% , white corn16%, dry banana peels 50% and carob syrup 11%

ME (MJ/kg DM) = 0.15 × IDMD (MAF, 1975)

CONCLUSION

The physical characteristics of silages (Colour, Smell, Moisture content and Presence of Mould) were mostly classified as being acceptable / Desirable for High Quality Silage. Crude Protein Content of Banana Peel Silage Mixed with Carob Syrup Was Higher Compared to Milos Silage. Therefore, Carob Syrup Should Provide for Quality Silages Suitable for Ruminants.

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