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Article

Characterization of Silage with Different Melon (*Cucumis melo* L) Biomasses and Dry Matter Contents

Romilda Rodrigues do Nascimento [1], Ricardo Loiola Edvan [1,*], Keuven dos Santos Nascimento [2], Dhiéssica Morgana Alves Barros [1], Lucas de Souza Barros [2], Luan Felipe Reis Camboim [2], Tairon Pannunzio Dias e Silva [1], Rafael de Souza Miranda [1], Marcos Jácome de Araújo [1], Anisio Ferreira Lima Neto [4], Leilson Rocha Bezerra [2], Francisco Naysson de Sousa Santos [5], Edson Mauro Santos [6] and Stelio Bezerra Pinheiro de Lima [1]

[1] Federal University of Piaui, Department of Animal Science, Teresina, 64000-900, PI, Brazil; romildarn01@ufpi.edu.br, edvan@ufpi.edu.br, morganabarros1@ufpi.edu.br, rsmiranda@ufpi.edu.br, jacome@ufpi.edu.br, pannunzio@ufpi.edu.br, steliolima@ufpi.edu.br

[2] Department of Animal Science, State São Paulo University, Jaboticabal, São Paulo, 14884-900 Brazil; keuven.s.nascimento@unesp.br

[3] Department of Animal Science, Federal University of Campina Grande, Campina Grande 58708-110, PB Brazil; lucas.barros1@estudante.ufcg.edu.br, leilson@ufpi.edu.br, luanzootec@ufpi.edu.br

[4] Brazilian Agricultural Research Company-EMBRAPA, Teresina, 64006-220, PI, Brazil. anisio.lima@embrapa.br

[5] Department of Animal Science, Federal University of Maranhão, 65500-000, MA; nayssonzootecnista@gmail.com

[6] Department of Animal Science, Federal University of Paraíba, CCA, Areia, 58.397-000 PB, Brazil. edson@cca.ufpb.br

* Correspondence: Corresponding author: edvan@ufpi.edu.br

Abstract: The objective of this study was to obtain different dry matter contents and proportions of melon plant biomass for silage making. A completely randomized design was adopted with a factorial scheme (3 × 2) in four replications. The first factor corresponded to three mixtures of melon biomass on as fed basis (AF) of plant (branch + leaf) and fruit (harvested melon) as follows: 100% plant, 90% plant + 10% fruit, and 100% fruit. The other factor corresponded to the ensiled material with fresh and dehydrated melon plant biomass (40% DM) which was dried in the field, after harvest. Silages with partial dehydration of the biomass available after fruit harvest with 0% and 10% fruit showed the greatest DM values: 297 and 293 g/kg DM, respectively. Silages with 0, 100 and 10% fruit showed medium LAB populations: 5.79, 5.14 and 4.58 logs CFU/g, respectively. Higher concentrations of acetic acid contents were observed in silages with 0 and 10% fresh fruit, which were 14.9 and 14.1 g/kg DM, respectively. Silages with 0% and 100% of dehydrated fruit showed better results for the indicators of good-quality silage. Dehydration improves the fermentative profile and quality of the melon silage.

Keywords: dehydration; fermentative indicators; nutrients; melon

1. Introduction

The fruit agroindustry produces tons of biomass annually, which is composed of different materials such as peels, seeds, and leaves that are discarded mainly due to its low nutritional value or for presenting inadequate sensory characteristics [1]. On the other hand, the utilization of this agro-industrial fruit biomass presents favorable nutritional characteristics for animal feeding, being a viable alternative for animal feed, especially in the form of silage [2]and the melon fruit biomass is an option for silage making.

After harvesting the commercial fruit in melon farming, a large volume of biomass (branches + leaves) and fruit (melon scraps) is available in the field and could be used to compose the diet of

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ruminants as silage. The conservation of this material in the form of silage is an option for animal feeding in melon producing regions, thus avoiding waste generating a new feed source for animals [3].

Some problems in the ensiling process, mainly regarding intrinsic factors of the plant, such as the low dry matter content which favors the multiplication of undesirable microorganisms that interfere directly in the fermentative and nutritional process of the ensiled mass causing nutrient losses [4]. Withering is a technique used in order to minimize losses in the ensiling process for biomasses that have high moisture content. This technique consists of leaving the material exposed to the sun for a few hours before crushing it, in order to raise the dry matter content of the material to be ensiled and thus prevent undesirable fermentations [5].

In order to obtain a silage of good fermentative and nutritional standards, it is necessary to know the factors that alter the dynamics of dry matter and nutrient losses. Similarly, the knowledge of fermentative indicators such as chemical composition, microbiology, stability, and organic acids is fundamental to achieve the productive efficiency of a silage [6].

Therefore, the objective of this study was to evaluate different dry matter contents and melon plant biomass proportions for silage making, through losses (gases and effluent), dry matter recovery, silage yield, microbiological dynamics, chemical composition and aerobic stability.

2. Materials and Methods

2.1. Statistical design and treatments

The completely randomized design was adopted with a factorial scheme (3 x 2) in four replications. The first factor corresponded to three mixtures on as fed basis (AF) of plant (branch + leaf) and fruit (harvested melon) as follows: 100% plant, 90% plant + 10% fruit, and 100% fruit. The other factor corresponded to the ensiled material with natural dry matter content (fresh) and with 40% dry matter content of (withered, after harvest).

2.2. Collection of melon plant biomass and silage making

The melon biomass was collected in a melon-producing rural property located in the region of Vale do Gurguéia, south of Piauí state. The melon season in the region lasts from July to October. The biomass harvest in the field was performed in September, 85 days after planting (DAP), and after three harvests of the commercial melon. Collection of melon plant biomass for silage preparation

The evaluations were performed after biomass collection where the green forage mass (GFM) was measured by PVC pipe square method: 0.5m x 0.5m (0.25m^2). After collection the material was fractioned according to the treatments, and taking to the oven to determine the dry matter content. The calculation of silage dry matter yield considered the dry matter recovery, through the equations: $DMY = (BIO * DM)/100$, where: DMY: Dry matter yield (t/hect); BIO: biomass (t); DM: dry matter (kg); and $Silage\ Yield = (DMY * DMR)/100$, where: Silage Yield (t/ha DM); DMY: dry matter yield (t/hect); and DMR: dry matter recovery (%).

The fresh material was processed in a silage machine. After being grounded part of the material was immediately ensiled, and another part was exposed to the sun for pre-drying, being turned over during this period to standardize dehydration. When the forage reached 40% DM it was gathered and ensiled. The determination of the DM content performed through the microwave method according to [7].

Experimental silos with a capacity of 3 kg made of polyvinyl chloride (PVC) were hermetically sealed, and packed to a density of 500 kg/m^3. The silos had a Bunsen-type valve adapted to the lid to allow the escape of fermentation gases and were opened after 90 days. All analyses were performed at the Laboratory of Animal Nutrition (LANA) of CPCE/UFPI.

2.3. Silage chemical composition and loss quantification

To determine the chemical composition of the silage, the contents of dry matter (934.01), mineral matter (981.10), crude protein (920.39) and ether extract (920.29) were determined according to [8].

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The analyses for determination of neutral detergent insoluble fiber (NDF) and acid detergent insoluble fiber (ADF), were performed according to [9]. The concentration of soluble carbohydrates (SC), was obtained through the concentrated sulfuric acid method, as described by [10] with adaptations by [11]. Buffering capacity (BCAP) was determined according to the methodology of [12]. The experimental silos were weighed after closure and opening, to determine dry matter (DM) losses through gases and effluents, and dry matter recovery (DMR) according to equations described by [13]. The chemical composition of the material before ensiling is presented in Table 1.

Table 1. Chemical composition of melon plant biomass before ensiling.

Analyses	100% Plant	90% Plant + 10% Fruit	100% Fruit
Dry matter (g/kg)	150.2	174.6	98.8
Mineral matter (g/kg DM)	79.1	73.5	80.6
Crude protein (g/kg DM)	46.5	54.6	57.4
NDF[1](g/kg DM)	652.0	597.2	472.9
ADF[2](g/kg DM)	428.8	319.2	276.7
pH[3]	7.29	7.95	6.53
N-NH3 [4](%)	0.68	0.63	0.95
CHO[5](g/kg)	92.7	120.0	174.0
Buffer Cap.[6]	22.62	10.29	6.74

[1]Neutral detergent insoluble fiber; [2]Acid detergent insoluble fiber; [3]Hydrogen potential; [4]Ammonia nitrogen based on total N; [5]Soluble carbohydrates; [6]Buffer capacity (e.mg NaOH/100 g/DM).

2.4. Silage fermentation indicators and microbiological analysis

Part of the silage was separated for analysis pH and ammoniacal nitrogen in total nitrogen (N-NH3/NT), following the method described by [14]. The microbiological evaluation of the populations of lactic acid bacteria, enterobacteria, quantification was made from the cultivation of colony forming units (CFU) in selective culture media, namely: MRS Agar (Kasvi) with the addition of nystatin (Control of Undesirable Microorganisms - CMI) after sterilization and incubation for 72 hours at 37°C, Violet Red Bile Lactose (Kasvi) with addition of nystatin (CMI) and incubation for 24 hours at 37°C, and Potato Dextrose Agar (Kasvi), with addition of tartaric acid (CMI) after two days incubation at 26°C in a B.O.D [15]. Values between 30 and 300 CFU per plate were considered countable.

2.5. Organic acids determination and aerobic stability

Organic acids were determined on a Shimadzu liquid chromatograph, SPD-10A VP (HPLC), coupled to an ultraviolet (UV) detector, at a wavelength of 210 nm, according to [16].

The aerobic stability test was performed (expressed in hours) was assessed by monitoring the internal temperature of the silages exposed to air over. The silos were opened and 1.5 kg of silage were placed in plastic buckets and transported with controlled temperature (25°C) similar to the evaluations performed by [17]. Temperatures were checked every four hours by digital skewer thermometers positioned in the center of the silage mass. The start of deterioration was considered when the internal temperature of the silages reached 2°C above room temperature [18]. Samples were taken from the contents of the buckets for pH measurement and microbiological analysis.

2.6. Statistical analysis

The data were subjected to analysis of variance. Means were analyzed through Tukey's test and compared with significance of $P<0.05$. The data were analyzed by the SISVAR software version 5.0 [19], according to the following equation:

$$Yijk = \mu + \tau i + \gamma j + (\tau\gamma)\, ij + \varepsilon ijk$$

where: Yijk = observation referring to the different mixtures of the melon biomass i with dehydration j; μ = general constant; τi = effect of the different mixtures of melon biomass with dehydration i; i = 1,

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2, 3; (100% plant, 90% plant + 10% fruit, 100% fruit); γj = is the effect of dehydration (fresh and 40%); (τγ)ij = interaction between the different mixtures of melon plant biomass i with dehydration j; εijk = random error associated to each mixture of melon plant biomass with dehydration.

3. Results

3.1. Silage yield and chemical composition

It was found effect of interaction ($P<0.05$) of the different biomass mixtures (increased inclusion of melon in the silage, 0, 10 and 100% AF) without or with dehydration on silage yield, dry matter (DM) and ether extract (EE), and isolated effect ($P<0.05$) of the amount of fruits in the ensiled biomass on neutral detergent insoluble fiber (FDN). No effect ($P>0.05$) was found on crude protein, acid detergent insoluble fiber and mineral matter contents of silages with different dehydrated melon plant biomasses (Table 2).

The silage with 10% fruit and dehydration presented the highest yield, 8.94 t/ha DM. Silages with partial dehydration of the available biomass after melon fruit harvest with 0% and 10% fruit showed the greatest DM contents, which were 297 and 293 g/kg DM, respectively.

Table 2. Chemical composition of silages with different melon plant biomasses according to dehydration.

Deh.[1]	Quantity of fruit (QF)			Mean[2]	SEM[3]	*P - value*		
	0%	10%	100%			Deh.[1]	QF	Deh.[1]×QF
Silage yield								
Without	3.96Bb	4.91Ba	1.75Bc	3.54	0.28	<0.01	<0.01	<0.01
With	6.50Ab	8.94Aa	3.28Ac	6.24				
Mean[2]	5.23	6.93	4.51					
Dry matter (g/kg)								
Without	215aB	205aB	135bB	185				
With	297aA	293aA	249bA	280	0.28	<0.01	<0.01	<0.01
Mean[2]	256	249	192					
Crude Protein (g/kg DM)								
Without	60.8	56.5	61.5	60.9				
With	60.9	60.4	55.4	57.6	0.16	0.17	0.61	0.56
Mean[2]	60.9	58.4	58.6					
Neutral Detergent Insoluble Fiber (g/kg DM)								
Without	653	604	651	659				
With	670	661	608	636	1.53	0.23	0.05	0.57
Mean[2]	683a	629b	616b					
Acid Detergent Insoluble Fiber (g/kg DM)								
Without	387	439	424	415				
With	372	391	402	389	1.62	0.26	0.41	0.86
Mean[2]	380	413	414					
Ether Extract (g/kg DM)								
Without	35.0cA	50.8bA	88.8aA	63.6				
With	31.1cA	45.8bB	84.1aA	56.0	0.20	0.02	<0.01	<0.01
Mean[2]	33.0	49.8	86.4					
Mineral Matter (g/kg DM)								
Without	73.0	77.5	82.4	77.7				
With	82.2	94.8	76.0	84.3	0.29	0.12	0.23	0.08
Mean[2]	77.6	86.2	79.2					
Soluble Carbohydrates (g/kg DM)								
Without	62.5	79.9	152	98.4	0.22	0.89	<0.01	0.33
With	69.8	76.3	150	98.8				
Mean[2]	66.1c	78.1b	151.5a					

[1]Deh: dehydration. [2]Mean. [3]SEM: standard error of the mean. Means followed by uppercase letters in the column and lowercase in the rows differ according to Tukey's test P<0.05.

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The silage with 0% fruit presented the greatest NDF content: 683 g/kg DM, showing that the addition of the fruit with dehydration affects the reduction of NDF values. The silage with 100% fruit ha the greatest EE values, with and without dehydration (88.8 and 84.4 g/kg DM, respectively). As for the soluble carbohydrates, the greatest contents were also recorded in silages with 100% fruit (151.5 g/kg DM).

3.2. Losses, DM recovery and fermentation indicators

There was effect of interaction (P>0.05) of the different biomass mixtures (0, 10 and 100% fruit AF in the biomass) and dehydration (without and with) on gases and ammonia nitrogen in the silages evaluated (Table 3). It was found a signifficant difference (P<0.01) according to the amount of fruit for recovery and pH of the silages produced with the different mixtures of melon biomass.

Table 3. Fermentation losses of silages with different melon plant biomasses and according to dehydration.

Deh.[1]	Quantity of fruit (QF)			Mean[2]	SEM[3]	*P - value*		
	0%	10%	100%			Deh.[1]	QF	Deh.[1]×QF
			Effluent (kg/t AF)					
Without	49.9	51.2	53.1	51.4				
With	50.3	49.3	57.0	52.2	2.07	0.7	0.3	0.7
Mean[2]	50.1	50.3	55.1					
			Gases DM (%)					
Without	2.0Ab	2.0Ab	4.5Aa	2.8				
With	2.0Ac	1.4Bb	3.5Ba	2.3	0.0	<0.01	<0.01	<0.01
Mean[2]	2.0	1.7	4.0					
			DM Recovery (%)					
Without	79.2	62.5	64.1	68.7				
With	78.1	69.7	67.6	70.6	0.6	0.6	<0.01	0.27
Mean[2]	78.6a	64.1b	64.9b					
			pH					
Without	7.95	7.84	4.70	6.83	0.29	0.65	<0.01	0.53
With	8.43	7.35	4.15	6.64				
Mean[2]	8.13a	7.60a	4.41b					
			N-NH_3(% TN)[4]					
Without	0.95aA	0.47bB	0.99aA	0.80	0.05	0.43	0.02	<0.01
With	0.59aB	0.79aA	0.85aA	0.74				
Mean[2]	0.77	0.63	0.92					

[1]Deh: dehydration. [2]Mean. [3]SEM: standard error of the mean. N-NH_3 (% TN)[4] ammonia nitrogen in relation to the percentage of total nitrogen. Means followed by uppercase letters in the column and lowercase in the rows differ according to Tukey's test P<0.05.

The highest gas loss (GAS) was recorded in silages with 10 and 100% fruit (2.0 and 4.5%) without dehydration. Silages with 0% fruit had the highest DM recovery, 78.6. Silages with 0% and 10% fruit had the highest pH values, which were 8.13 and 7.60. The greatest ammonia nitrogen (N-NH_3) values were found in silages with 0% and 100% fruit (0.95 and 0.99% TN) without dehydration.

3.3. Microbiology analysis of silages

It was found effect of interaction (P<0.01) of the different biomass mixtures (increased inclusion of melon in silage, 0, 5, 10, 20 and 100% AF) and dehydration (without and with) on mold populations (Table 4). It was also found effect (P<0.05) of the different mixtures on lactic acid bacteria, yeasts and enterobacteria populations.

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Table 4. Population of microorganisms in silages with different melon plant biomasses according to dehydration.

Deh[1]	Quantity of fruit (QF)			Mean[2]	SEM[3]	*P - value*		
	0%	10%	100%			Deh.[1]	QF	Deh.[1]×QF
Lactic acid bacteria (CFU/g)								
Without	4.18	4.88	5.72	4.81				
With	5.39	5.29	7.76	5.52	0.5	0.05	0.04	0.96
Mean[2]	4.78a	5.08a	5.96a					
Yeasts (CFU/g)								
Without	0.0	0.0	4.95	1.53				
With	0.0	0.0	4.59	1.65	0.6	0.07	<0.01	0.90
Mean[2]	0.0b	0.0b	4.77[a]					
Molds (CFU/g)								
Without	2.50Aa	0.0Bb	3.66Aa	2.05				
With	2.86Aa	4.0Aa	3.19Aa	3.35	0.5	<0.01	<0.01	<0.01
Mean[2]	2.68	2.0	3.42					
Enterobacteria (CFU/g)								
Without	3.45	3.54	0.0	2.33				
With	2.72	2.44	0.0	1.72	0.1	<0.01	0.12	0.13
Mean[2]	3.09a	2.99a	0.0b					

[1]Deh: dehydration. [2]Mean. [3]SEM: standard error of the mean. Means followed by uppercase letters in the column and lowercase in the rows differ according to Tukey's test P<0.05.

Silages with 0, 100 and 10% fruit presented mean values of LAB populations of 4.78, 5.08 and 5.96 logs CFU/g, respectively. While the biggest yeast populations were recorded in silages with 100% fruit (4.77log CFU/g). Silages with 10% fruit and dehydration showed the highest mold population value (4.00 CFU/g). As for enterobacteria, the highest values were found in silages with 0 and 10% fruit, which were 3.09 and 2.99 log CFU/g.

3.4. Organic acids

Regarding the organic acids, it was found effect of interaction (P<0.05) between different biomass mixtures (increased inclusion of melon in silages, 0, 10 and 100% AF) and dehydration (without and with) on lactic, acetic and propionic acid contents, while the quantity of fruit caused difference (P<0.01) in the content of butyric acid (Table 5).

Silages with 10 and 100% dehydrated fruit showed higher contents of lactic acid (6.5 and 12.7 g/kg DM, respectively). Acetic acid concentration was higher in silages with 0 and 10% fruit without dehydration (14.9 and 14.1 g/kg DM, respectively). As for propionic acid, the greatest value was recorded in silages with 0 and 10% fruit without dehydration (5.7 and 4.4 g/kg DM). And the greatest amounts of butyric acid were found in silages with 0% and 10% fruit (5.2 and 3.9 g/kg DM).

Table 5. Contents of organic acids in silages with different melon biomasses according to dehydration.

Deh.[1]	Quantity of fruit (QF)			Mean[2]	SEM[3]	*P - value*		
	0%	10%	100%			Deh.[1]	QF	Deh.[1]×QF
Lactic acid (g/kg DM)								
Without	0.7Bb	2.2Bb	11.2Aa	4.7				
With	4.4Ac	6.5Ab	12.7Aa	7.5	0.4	<0.01	<0.01	<0.01
Mean[2]	2.5	4.3	11.5					
Acetic acid (g/kg DM)								
Without	14.9Aa	14.1Aa	3.8Ab	6.4				
With	9.2Ba	5.5Bb	4.5Ab	10.9	0.4	<0.01	<0.01	<0.01
Mean[2]	12.1	9.8	4.2					
Propionic acid (g/kg DM)								

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Without	5.7Aa	4.4Ab	1.1Bb	2.7				
With	3.6Ba	2.1Bb	2.3Ab	3.7	0.2	<0.01	<0.01	<0.01
Mean[2]	4.6	3.2	1.7					
Butyric acid (g/kg DM)								
Without	4.1	3.5	1.5	3.9				
With	6.3	4.4	1.1	3.0	0.6	0.08	<0.01	0.14
Mean[2]	5.2a	3.9a	1.3b					

[1]Deh: dehydration. [2]Mean. [3]SEM: standard error of the mean. Mean followed by uppercase letters in the column and lowercase in the rows differ according to the Scott-Knott test $P<0.05$.

3.5. Aerobic stability

It found effect of interaction ($P<0.05$) between the different biomass mixtures (0, 10 and 100% fruit) and dehydration (without and with) on aerobic stability (Table 6). And the amount of fruit had effect ($P<0.05$) on pH.

Table 6. Aerobic stability of silages with different melon plant biomasses according to dehydration.

Deh[1]	**Quantity of fruit (QF)**			**Mean[2]**	**SEM[3]**	***P - value***		
	0%	**10%**	**100%**			**Deh.[1]**	**QF**	**Deh.[1]×QF**
Hours								
Without	28.0Bc	88.0Aa	64.0Ab	40				
With	36.0Aa	36.0Ba	48.0Ba	60	0.0	<0.01	<0.01	<0.01
Mean[2]	32.0	56.0	62.0					
Internal temperature (ºC)								
Without	28.75	27.5	27.87	28.04				
With	28.25	27.5	27.62	27.79	1.0	0.05	0.15	0.88
Mean[2]	28.5	27.5	27.7					
pH								
Without	8.15	7.15	3.92	8.1				
With	8.17	4.45	4.25	8.1	0.1	0.6	<0.01	0.27
Mean[2]	8.1A	5.8B	4.08C					

[1]Des: dehydration. [2]Mean. [3]SEM: standard error of the mean. Means followed by uppercase letters in the column and lowercase in the rows differ according to Tukey's test $P<0.05$.

Silages with 100% with dehydration showed aerobic stability break at 48 hours. The highest pH value was found in the silage with 0% fruit (8.1) It was found effect of interaction ($P<0.05$) between the different biomass mixtures (increased inclusion of melon in silage, 0, 10, 100% AF) and the dehydration on stability for enterobacteria and molds, and significant effect of the amount of fruit on yeasts (Table 7).

Table 7. Population of microorganisms in silages produced from melon plant biomass with different mixtures according to dehydration.

Deh[1]	**Quantity of fruit (QF)**			**Mean[2]**	**SEM[3]**	***P - value***		
	0%	**10%**	**100%**			**Deh.[1]**	**QF**	**Deh.[1]×QF**
Lactic acid bacteria (CFU/g)								
Without	5.20	4.23	5.30	4.91				
With	5.06	4.70	5.03	4.93	0.7	0.9	0.30	0.72
Mean[2]	5.13	4.46	5.16					
Yeats (CFU/g)								
Without	0.0	0.0	5.10	1.7				
With	0.0	3.76	0.0	1.25	0.6	0.07	<0.01	0.90
Mean[2]	0.0b	1.88b	2.55[a]					
Molds (CFU/g)								
Without	2.50Bb	5.20Aa	0.0Bc	2.56	0.19	0.9	<0.01	<0.01
With	3.50Aa	1.90Bb	3.43Aa	2.94				

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Mean[2]	3.0	3.55	1.71					
			Enterobacteria (CFU/g)					
Without	2.93Aa	3.0Aa	0.0Ab	0.0				
With	0.0Ba	0.0Ba	0.0Aa	1.97	0.1	<0.01	<0.01	<0.01
Mean[2]	1.46	1.50	0.0					

[1]Des: dehydration. [2]Mean. [3]SEM: standard error of the mean. Means followed by uppercase letters in the column and lowercase in the rows differ according to Tukey's test $P<0.05$.

There was no presence of yeasts in silages with 0% fruit (Table 7). For mold population in aerobic stability, it was observed higher values in silages with 0 and 100% fruit (3.50 and 3.43Log/CFU/g[1]). Enterobacteria were not counted in silages with 100% fruit with and without dehydration.

4. Discussion

4.1. Silage yield and chemical composition

The biomass with 10% dehydrated fruit produced more silage, with this response being related to the management of the crop, besides the dehydration causing a greater silage yield (Table 2). In addition to high yield, the fruit is expected to have superior quality, which is related to the management to which the crop is subjected during its cycle, on which the soluble solids content will depend [20].

Silages with partial dehydration of the biomass available after harvesting the melon fruit with 0% and 10% fruit had high DM contents (Table 2). This shows that dehydration increased the dry matter contents of the biomass, as can be seen in terms of DM before ensiling (Table 1). According to [21], for an adequate fermentation process to occur, the material before ensiling should have at least 30 g/kg of DM, which is close to that found in this study. According to [22], the dehydration or wilting technique can improve some characteristics of the ensiled material as dry matter, and thus promote better fermentation in the stored silage.

The NDF content showed higher value in silages with 0% fruit, demonstrating that the addition of the fruit with dehydration, influences the reduction of NDF values. According to [23], the recommended values of NDF vary between 550 to 600 g/kg DM, and the values found in this study fall within this range. According to [24], the NDF values are part of the fiber fraction of the roughage and high values can be harmful, because they hinder degradation by microorganisms in the digestible tract of the animals, reducing the nutritional quality, but when the fruit was added and the biomass dehydrated, there was a reduction in the NDF values.

Regarding the EE content, high values were observed in the silage with 100% fruit, with and without dehydration. These results are mainly related to the seeds of the melon fruit that contain a higher amount of fat. According to [25] this vegetable stores its energy in the grain in the form of oil. According to [26], EE values should not exceed the maximum level of 50 g/kg DM in ruminant diets, are lower than the values found in this study. This indicates that it is not recommended to provide the melon fruit silage as the only source of roughage for ruminants.

The silage with 100% fruit had the highest soluble carbohydrates value, and this fact is related to the higher amount of soluble carbohydrate present in the melon fruit, which is suitable for silage making (Table 1). The wilting process did not influence the amount of total soluble carbohydrates. According to [27] for silages to present good fermentation it is necessary that the ensiled mass has adequate levels of soluble carbohydrates. Plants that have high carbohydrate content provide a suitable medium for the growth of desirable microorganisms, however, excess soluble carbohydrates can predispose the medium to undesirable fermentations resulting in losses that can affect the dry matter content of the forage [28]and its nutritional value.

4.2. Losses, DM recovery and fermentation indicators

Gas losses (GAS) were higher in silages with 10 and 100% fruit (Table 3). The gas losses that occur inside the silo are due to secondary fermentations. In this study, low losses through effluent

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and gases were recorded, indicating that the secondary fermentations were insignificant. According to [29], the formation of gases in silages, is the result of secondary fermentations, exerted by Enterobacteria, clostridia bacteria and aerobic microorganisms, which normally grow in higher pH media.

The silage with 0% fruit showed the highest dry matter recovery. The dry matter recovery rate (DMR) is highly influenced by losses due to effluent and gas production in silages. Silages with the highest DM contents resulted in increased DMR, which can also be observed by the reducing losses as gases and effluents. According to [30], cases of undesirable fermentations less than 80% cause significant losses through the production of heat inside the silo, producing CO2 and organic acids such as butyric that does not get to be preserved the ensiled material.

Silages with 0% and 10% fruit had the highest pH values, which can be attributed to the high buffer capacity of the plant branch (leaf + branch) of 22.62 e.mg NaOH/100 g/DM (Table 1). Some factors could have contributed for the pH not to decrease, such as the constituents of the melon plant biomass, preventing the pH of the ensiled mass to reduce from 3.8 to 4.2, which is desirable in ensiled material [31] The silage dehydration process had an influence on the results, because it decreases the water levels of the forage, increasing the dry matter, providing a good fermentation and a production of lactic acid bacteria that are responsible for decreasing the pH [27].

Silages with 0% and 100% fruit without the dehydration the highest ammonia nitrogen (N-NH3). Indicating lower intensity of proteolysis during the fermentation process, since the values were lower than recommended. The N-NH3 reflects the breakdown of protein during the fermentation process, thus, these silages can be classified according to the content of ammonia nitrogen in relation to the total nitrogen, being excellent when values are lower than 10%, indicating that there was no excessive protein breakdown [32].

4.3. Microbiology analysis of silages

Silages with 0, 100 and 10% fruit presented LAB populations, since dehydration contributes to the availability of substrate for the multiplication of these bacteria. Besides, the reduction of pH occurs through the production of lactic acid, thus the proliferation of these microorganisms ensures the stability of the ensiled mass and the preservation of the material [33].

The greatest yeast value was observed in the silage with 100% fruit. The presence of big yeast populations in silages is worrisome due to their potential for multiplication after the opening of the silo. After oxygen penetration in the silage, they use lactic acid for energy production and multiplication, raise the pH of the silage exposed to air [34] and cause heating, causing that silage achieve the break of aerobic stability more quickly (Table 5).

The silages with 10% dehydrated fruit had the highest number of molds. The presence of mold throughout the fermentation period may indicate that the amounts of organic acids produced were not sufficient to inhibit the production of these microorganisms, as they are the main responsible for the aerobic deterioration of silages, after the opening of the silo as suggested by [35].

Regarding the Enterobacteria, the highest values were found in silages with 0 and 10% fruit. This was possibly due to the lower levels of lactic acid and higher pH values, as these microorganisms develop in higher pH ranges. According to [36] the growth of Enterobacteria is undesirable since these microorganism ferment carbohydrates into acetic acid, and also have the ability to degrade amino acids.

4.4. Organic acids

Silages with 10 and 100% dehydrated fruit had higher levels of lactic acid, since the increase in the concentration of this acid is evidenced by the dehydration, which promoted increase in the activity of LABs, decrease in pH values and a better relationship between lactic and acetic acids. Although all acids formed in fermentation contribute to reducing the pH of silage, lactic acid plays a key role in this process, because it has a higher dissociation constant in comparison to the others [37].

Higher concentrations of acetic acid were observed in silages with 0 and 10% fruit without dehydration. The higher acetic acid contents in the non-wilted silages are probably associated with

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the lower rate of pH decline, which may be a result of the lower efficiency of LABs in dominating the fermentative process, favoring other acetic acid-producing microorganisms.

Regarding propionic acid, a higher value was observed in silages with 0 and 10% fruit without dehydration, where the lower concentration of this acid in the wilted silages is explained by the greater control of secondary fermentations that result in the formation of other organic acids. The propionic acid values of 5.4 and 3.2 g/kg DM for non-wilted and wilted silages respectively, at the end of the fermentation period, are within the acceptable range of production of this acid that, according to [38], which should be from 1 to 10 g/kg DM to obtain good quality silage.

For butyric acid, higher values were observed in silages with 0% and 10% fruit. The withering favored the reduction of butyric acid concentration, justifiable by the increase in DM content. According to [31] the presence of butyric acid is not desired, since it is considered a product of undesirable fermentation from bacteria of the genus Clostridium.

4.5. Aerobic stability and microbiology analysis

The break in stability occurred in silages with 100% fruit (Table 6) and these results can be explained by the presence of fermentable substrates in the silage, where aerobic deterioration is associated with decreased soluble carbohydrates and lactic acid; increased pH, increased number of yeasts and filamentous fungi [35]as well as temperature [39].

The highest pH value was observed in the silage with 0% fruit without dehydration, which can be attributed to the high buffer capacity of the plant branch (leaf + branch) of 22.62 e.mg NaOH/100 g/DM (Table 1) which even after exposure to oxygen remained high. [39] stated that pH variation during the air exposure period can be a practical indication that the silage is being spoiled due to contact with air, which demonstrates greater susceptibility to silage spoilage even with dehydration.

Silages with 0% fruit had no presence of yeasts, indicating that these silages showed higher resistance to deterioration due to the low lactic acid value. The presence of yeast plays an important role in the deterioration of silage and may have occurred due to the low amount of residual sugars available, as they degrade lactic acid into carbon dioxide and water, producing excessive heat leading to nutrient loss [40].

There was no count of Enterobacteria in silages with 100% fruit with and without dehydration. Enterobacteria compete with lactic acid bacteria for the consumption of soluble carbohydrates, thus the reduction in pH of the medium can inhibit or decrease the development of Enterobacteria and Clostridium being an effect of dehydration [13].

For mold population in aerobic stability, higher values were observed in silages with 0 and 100%. This may be related to the time the silages spent in aerobic exposure and the lower aerobic stability of the silage, corroborating with what was observed by [41] who reported that the presence of oxygen triggers the reproduction of microorganisms in the silage, promoting proliferation.

5. Conclusions

The silages with 0% and 100% dehydrated fruit showed better results for the evaluative indicators in relation to a good quality silage. Dehydration improves the fermentative profile and the quality of melon silage.

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