Ensiling Process of Horticultural By-Products

Subjects: Zoology

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Commercial round bale silos is made by wastes from artichoke and broccoli crops and cannery whose industries represent an environmental problem. A viable option to this problem is ensiling them for use as ruminants feed. Twenty-one commercial round bale silos (300 kg and 0.64 m3) of each by-product were made. Samples were analysed at days 0, 7, 15, 30, 60, and 200 to determine microbial populations, fermentation metabolites, nutritional components, and phytosanitary residues. Feedstuffs showed good suitability for ensiling, and stabilisation was achieved on day 30. The variables with the greatest significant differences among sampling times were microbial populations and fermentative components. There were no important dry matter losses, and some significant differences were observed in the nutritional composition, especially in crude protein and fibrous fractions, but they were not relevant for the loss of nutritional quality of silages. The phytosanitary residues determined on day 200 were below the maximum residue limits set by European legislation. So, ensiling these by-products in commercial round bale silos is a suitable and profitable technique that allows their preservation for a long time (200 days).

Keywords: Silage ; nutritive value ; ruminant feeding ; alternative feeds ; feedstuff

1. Introduction

Artichoke and broccoli crops are widespread throughout the world, mainly in the Mediterranean region [1]. After artichoke harvests and industrial processing of artichoke and broccoli, large amounts of by-products are generated [2][3]. The use of these alternative and cheaper feedstuffs in ruminants' diets would reduce waste caused by the agri-food industry, disposal costs, and the land and natural resources used in animal feed production, contributing to the circular economy. Because of the high water content and the seasonality of these feedstuffs, ensiling might be a technology to preserve its nutritional quality for a long time [4], and this must be considered and studied at commercial scale.

2. Objective

The aim of this entry is to characterise the silage process of broccoli and artichoke by-products and artichoke plant stubble in commercial size silos (300 kg round bale) over 200 days to determine the quality and suitability of these types of silages as a ruminant feed and its shelf life. Changes in variables related to the fermentation process, microbial population dynamics, nutritional composition,

fermentative components, and in vitro digestibility were studied. The hypothesis of this study is that the commercial-scale silage technique of these by-products in 300 kg round-bale silos will allow food preservation for a long period of at least 200 days. The advantages of these types of silos over others are that they are easy to transport, can be sold as a package, have high compaction, good storage life, and no construction costs.

3. Material and methods

Twenty-one round bale silos of 300 kg and 0.64 m^3 of broccoli by-product (BB), artichoke by-product (AB) and artichoke plant stubble (APS) were made following the procedure outlined in Figure 1. Samplings of each type of silage were carried out on days 0, 4, 7, 10, 15, 30, 60 and 200. Microbiological determinations were of enterobacteria, aerobic mesophilic bacteria, lactic acid bacteria, yeasts and moulds were made following AENOR procedures [5]. Clostridium spores cultures were performed by methodology indicated in Arias et al. [6]. Variables analysed were physico-chemical parameters (pH and buffer capacity) and nutritional composition: dry matter, organic matter, ether extract and crude protein, as described in AOAC procedures [7]; neutral detergent fibre, acid detergent fibre, acid detergent lignin [8]; in vitro dry matter digestibility [9], and total polyphenols [10]. Metabolites resulting from fermentation proccess were determined: sugars, lactic acid, acetic acid, butyric acid and ethanol and ammonia N [11].

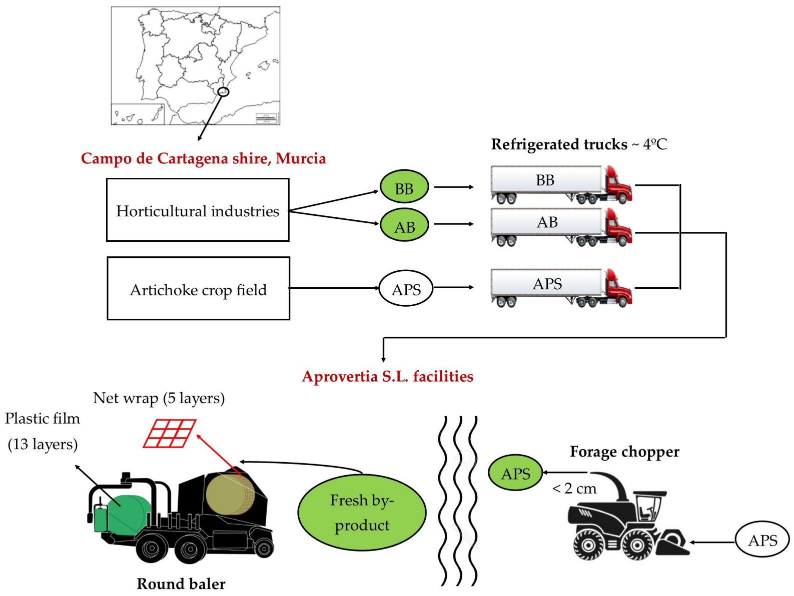

Figure 1. Ensiling process of the three by-products studied.

4. Results

4.1. Microbiology

Figure 2 shows the effect of ensiling on microbial populations.

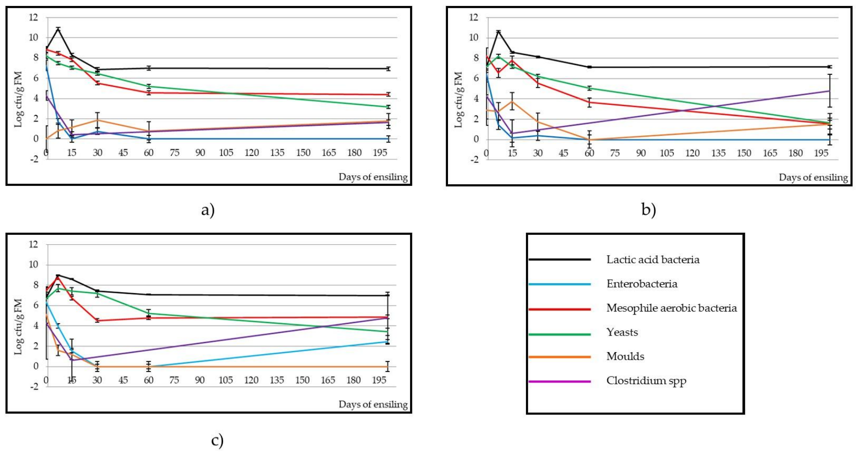

Figure 2. Effect of ensiling on microbial populations in broccoli by-product (a), artichoke by-product (b) and artichoke plant stubble (c) silages.

4.2. Physico-Chemical Parameters and Nutritional Composition

Figure 3 shows the effect of ensiling on Flieg scores and pH.

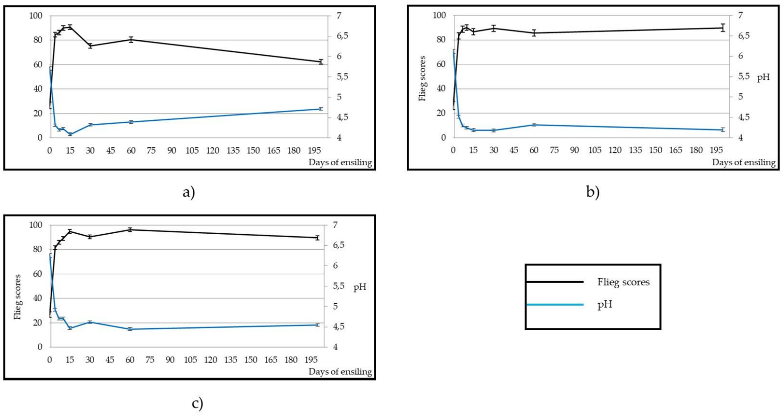

Figure 3. Effect of ensiling on Flieg scores and pH in broccoli by-product (a), artichoke by-product (b) and artichoke plant stubble (c) silages

Changes in nutritional composition during the 200 days of silage are shown Table 1.

Table 1. Effect of ensiling on nutritional composition, in vitro dry matter digestibility and total polyphenols content in broccoli by-product (BB), artichoke by-product (AB) and artichoke plant stubble (APS) silages.

Silage	Days of Ensiling								SEM	*p*-Value
	0	4	7	10	15	30	60	200		
Dry matter (g/kg)										
BB	174bc	184ab	172bc	197ab	173bc	142d	181ab	154cd	6.79	***
AB	256a	220b	203bcd	201bcd	207bc	183d	192cd	190cd	8.66	***
APS	283abc	291abc	273cd	286abc	268d	277bcd	271cd	258e	4.21	***
Organic matter (g/kg DM)										
BB	849a				840a	826b	828b	821b	3.5	***
AB	912				927	912	912	916	9.4	n.s.
APS	839b				849a	837b	833bc	828c	2.3	***
Ether extract (g/kg DM)										
BB	20.2b				23.4b	29.1a	23.2b	32.1a	1.97	**
AB	19.6				29.3	25.8	28,0	29.6	3.41	n.s.
APS	26.3b				31.4ab	35.7a	34.7a	34.6a	2.22	*
Crude protein (g/kg DM)										
BB	195a				199a	204a	153c	174b	4.6	***
AB	117b				126b	125b	122b	145a	3.7	***
APS	78.7a				78.3a	67.1b	76.9a	78.1a	1.2	***
Neutral detergent fibre (g/kg DM)										
BB	395ab				356bc	311d	342cd	430a	11.7	***
AB	589a				530ab	510b	541ab	528ab	17.1	*
APS	547ab				555ab	540b	532b	571a	9.9	**
Acid detergent fibre (g/kg DM)										
BB	272b				266b	233c	259b	326a	8.2	***
AB	398				359	353	379	354	13.3	n.s.
APS	358ab				365a	361a	336b	374a	7.3	***
Acid detergent lignin (g/kg DM)										
BB	77.9a				65.0b	35.1c	35.1c	63.4b	3.63	***
AB	131a				81b	80b	84b	89b	6.8	***
APS	84.5bc				87.1b	91.9b	77.1c	107.9a	2.67	***
In vitro dry matter digestibility (g/kg DM)										
BB	888a				829b	857ab	800b	822b	14.7	**
AB	670b				724ab	723ab	737ab	769a	23.2	*
APS	606b				579c	632a	629ab	615ab	7.1	***
Total polyphenols (g/kg DM)										
BB	5.86c				8.85a	9.59a	7.48b	6.73ab	0.308	***
AB	1.96d				7.60c	10.08b	15.29a	7.56c	0.734	***
APS	5.02b				5.47ab	5.95a	5.55ab	4.96b	0.240	**

a–e Different letters in the same row indicate significant difference between days. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; n.s.: non significant.

4.3. Fermentation

Figure 4 shows the effect of ensiling on sugar content and fermentative components.

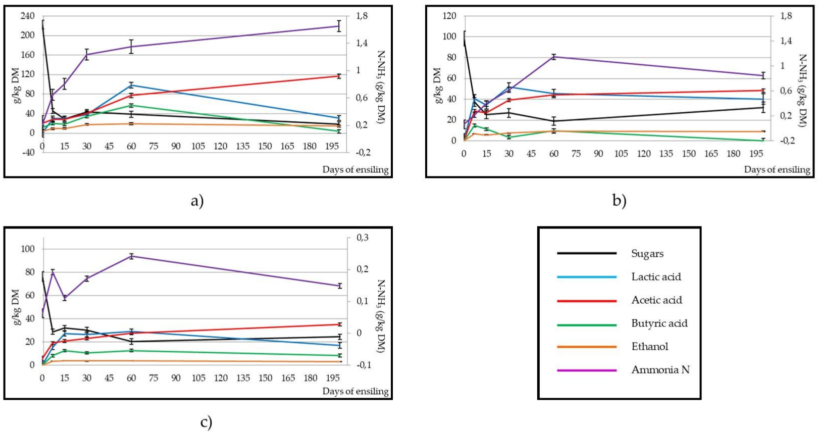

Figure 4. Effect of ensiling on sugar content and fermentative components in broccoli by-product (a), artichoke by-product (b) and artichoke plant stubble (c) silages.

4.4. Phytosanitary Residues Evaluation

Any phytosanitary residue exceeded the MRLs set by European legislation, although APS was the by-product in which a greater number of phytosanitary residues was detected, as shown in Table 2.

Table 2. Phytosanitary residues (mg/kg) in silages after 200 days of ensiling in round bales broccoli by-product (BB), artichoke by-product (AB) and artichoke plant stubble (APS) silages.

Phytosanitary	Type	BB	AB	APS	MRL	Legislation
Cypermethrin	Insecticide	n.d.	n.d.	0.240	2.00	UE 520/2011
Chlorpyrifos	Insecticide	n.d.	n.d.	0.085	1.00	CE 839/2008
Imidacloprid	Insecticide	0.023	n.d.	0.034	0.50	UE 491/2014
Miclobutanil	Fungicide	n.d.	0.044	0.220	0.50	UE 2016/567
Spirotetramat	Insecticide	0.053	n.d.	n.d.	1.00	UE 2015/845
Triadimefon	Fungicide	n.d.	n.d.	0.700	1.00	CE 459/2010

MRL: Maximum Residue Limit; n.d.: Not Detected.

4.5. Manufacturing Costs

The cost of the three silages was much lower than that of other ingredients that are part of a conventional diet for ruminants (Table 3).

Table 3. Approximate manufacturing costs (€/t) of broccoli by-product (BB), artichoke by-product (AB) and artichoke plant stubble (APS) silages in 300 kg round bale silos on commercial scale.

Costs	BB	AB	APS
Raw material	4	10	5
Inner netwrap and plastic film	7.9	7.6	8.1
Workforce, other production and marketing costs	7.3	7.3	7.3
Total (fresh matter)	19.2	24.9	20.4
Total (dry matter)	125	131	79
Total (€/kg CP)	0.718	0.903	1.01

CP: crude protein.

5. Conclusions

According to the values obtained for microbiology, physico-chemical parameters and fermentative and nutritional components, stabilisation of studied by-products was achieved on day 30. Thereafter, most variables remained stable or were modified very slightly, as occurred with the count of microorganism populations. The silage's quality remained high until day 200, as was the hypothesis of this experiment. We may state that ensiling broccoli and artichoke by-products and artichoke plant stubbles in commercial round bale silos is a practical and profitable technique that seems promising because it allows for their conservation over time, especially with artichoke by-products, not affecting their nutritional composition. Further studies should be carried out using them as feed for animals to explore voluntary intake and its effect on production and animal health.

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