Ensiling Process in Commercial Bales of Horticultural By-Products from Artichoke and Broccoli

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Wastes from artichoke and broccoli crops and cannery industries represent an environmental problem. A viable option to this problem is ensiling them for use as ruminants' feed. The aim of this study was to characterise the ensiling process of broccoli and artichoke by-products and assess their suitability to be part of the ruminant diet, as well their minimum shelf life. 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).

INTRODUCTION

Artichoke and broccoli crops are widespread throughout the world, mainly in the Mediterranean region. After artichoke harvests and industrial processing of artichoke and broccoli, large amounts of by-products are generated. 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, and this must be considered and studied at commercial scale.

OBJECTIVE

The aim of this study 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.

MATERIAL AND METHODS

Twenty-one round bale silos of 300 kg and 0.64 m³ 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. Clostridium spores cultures were performed by methodology indicated in Arias et al. 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; neutral detergent fibre, acid detergent fibre, acid detergent lignin; in vitro dry matter
digestibility [9], and total polyphenols [10]. Metabolites resulting from fermentation process 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.

RESULTS

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.

Physico-Chemical Parameters and Nutritional Composition

Figure 3 shows the effect of ensiling on Flieg scores and pH.
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 |
|-------------|------------------|-----|---------|
| Dry matter  |                  |     |         |
| BH          | 0                | 7.8 |         |
| AB          | 1                | 8.6 |         |
| APS         | 2                | 9.2 |         |
| Crude protein |                | 10.4|         |
| BH          | 0                | 11.4|         |
| AB          | 1                | 12.5|         |
| APS         | 2                | 13.6|         |
| Acid detergent fibre (g DM) |            |     |         |
| BH          | 0                | 14.7|         |
| AB          | 1                | 15.8|         |
| APS         | 2                | 16.9|         |
| Total polyphenols (g DM) |            |     |         |
| BH          | 0                | 17.0|         |
| AB          | 1                | 18.1|         |
| APS         | 2                | 19.2|         |

Fermentation

Figure 4 shows the effect of ensiling on sugar content and fermentative components.
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      | n.d.| n.d.| 0.24| 2.0 | UE 529/2011 |
| Chlorpyrifos      | n.d.| n.d.| 0.08| 1.0 | CE 836/2008 |
| Imidacloprid      | 0.02| n.d.| 0.04| 0.5 | UE 435/2004 |
| Mibefradil        | n.d.| n.d.| 0.22| 0.5 | UE 264/1667 |
| Spirotetramat     | n.d.| n.d.| 1.00| 2.0 | UE 265/2065 |
| Tricloronitro      | n.d.| n.d.| 0.70| 1.0 | CE 456/2010 |

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 netwarp and plastic film | 7.9 | 7.6 | 8.1 |
| Workforce, other production and marketing costs | 7.3 | 7.3 | 7.3 |
| Total (fresh matter)       | 10.2| 24.9| 20.4|
| Total (dry matter)         | 12.5| 33.1| 28.9|
| Total (kg CP)              | 0.21| 0.008| 1.01|

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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Keywords

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

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