Ensiling capacity, chemical composition and multiresidue evaluation of fresh artichoke (Cynara scolymus, L.) by-product to be used in ruminant feeding

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Ensiling capacity, chemical composition and multiresidue evaluation of fresh artichoke *(Cynara scolymus,* L.*)* by-product to be used in ruminant feeding

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SUMMARY – Artichoke (*Cynara scolymus, L.*) by-product from industrial processing was ensiled in microsilos and sampled at different days. To evaluate its utilization in animal feeding, fermentative, chemical and different multiresidue parameters were determined. This by-product showed a good aptitude to be ensiled, a pleasant smell and good visual characteristics were obtained. The DM content was 29.8%; effluents were not detected during the ensiling of the artichoke by-product and it was stabilized after 12 days of ensiling the pH value being 4.1 at the end of the process. Not many losses were detected in chemical value after the ensilage period. On the other hand, prometryn was the only multiresidue found at day 0 (0.04 ppm); this concentration is below the minimum amount permitted by law. After 12 ensiling days, this herbicide was not detected. It can be concluded that the by-product evaluated can be used, after their ensilage without health risk in animal feeding.

Keywords: Artichoke, silage, by-product, multiresidues.

RESUME – *"Evaluation de la capacité d'ensilage, de la composition chimique et des multi-résidus du sous-produit frais d'artichaut (*Cynara scolymus*, L.)". Le sous-produit obtenu à l'issue du traitement industriel de l'artichaut (*Cynara scolymus*, L.) a été ensilé dans des microsilos et prélevé à différents jours. La valeur alimentaire de l'ensilage obtenu a été évaluée en déterminant les paramètres fermentaires et sa composition chimique et en vérifiant la présence de résidus phytosanitaires. Ce sous-produit a présenté une bonne aptitude à l'ensilage, une odeur agréable et de bonnes caractéristiques visuelles. La teneur en matière sèche du produit ensilé a été de 29,8%, et aucun effluent n'a été détecté pendant le processus d'ensilage de l'artichaut. L'état de l'ensilage s'est stabilisé après 12 jours et le pH a été de 4,1 à la fin du processus. La valeur nutritive n'a pas diminué au cours de la période d'ensilage. D'autre part, le seul résidu phytosanitaire détecté a été la prometryne au jour 0 (0,04 ppm). Cette concentration est en dessous de la limite autorisée par la loi. Après 12 jours d'ensilage, cet herbicide n'a pas été détecté. On peut conclure que le sous-produit évalué peut être utilisé après son ensilage sans risque sanitaire pour l'alimentation animale.*

Mots-clés : *Artichaut, ensilage, sous-produit, résidus phytosanitaires.*

Introduction

Recovering by-products for use as animal feed can help food processors save money while preventing pollution. Offering by-products for use as animal feed is an economical and environmentally sound way for food processors to reduce waste discharges and cut waste management costs. Selling by-products can also produce additional revenue. Livestock producers can save money as well if by-products offer a less expensive source of nutrients than traditional feeds and if they support acceptable animal performance (Megías *et al.*, 1991). To determine whether a material is appropriate for a particular animal feeding situation, producers should consider these other factors: types and proportions of by-products generated, variability in moisture and nutrient content, conservation of the material, handling characteristics, potential for the presence of physical or chemical contaminants (sticks, metal items, glass, plastic, insecticides, herbicides, bactericides and fungicides, etc.) potential for development of molds and related mycotoxins. At this moment, the presence of multiresidues as phyto-healths is of great interest for farmers and consumers.

The traditional problems usually encountered with by-products are seasonality of supply that is often accented by their high moisture content. Hence, they easily spoil creating a nuisance and are often wasted. Ensiling by-products is the most suitable method for their conservation for a long period.

Silage may be defined as moist forage in the absence of air and preserved by fermentation (McDonald *et al*., 1991). Fermentation is carried out by bacteria acting on plant carbohydrates in the chopped forage. The bacteria feed on the carbohydrates in the forage and rapidly produce volatile acids and lactic acid. When the production of this acid reaches a certain level, it prevents further bacterial action; resulting in the preserved feed we call silage.

The objective of this study was to know the ensiling capacity, chemical composition and, mainly, the multiresidues evaluation of fresh artichoke (*Cynara scolymus L.*) agroindustrial by-product to be used in ruminant feeding.

Material and methods

In this paper, the material of study was fresh artichoke (*Cynara scolymus L.)* by-product. This material was obtained from an industrial process, when the artichoke was cleaned by hand, before being scalded. The materials were carried to the laboratory and 8 polyethylene containers of 12.5 l capacity were filled with this by-product and sealed, except for a small opening at the base, which was sealed after seepage release.

The silos were opened and sampled, one each time, respectively after 1, 2, 3, 4, 8, 12, 24 and 50 days. Day 0 corresponds to the initial material before ensiling. Three samples were taken from the centre of each ensiled mass and they were frozen at -20ºC until analysis. Dry matter (DM), ash and crude protein (N Kjeldahl x 6.25) (CP) contents were determined (AOAC, 1984), such as water soluble carbohydrate (WSC) contents as described by Barnett and Millar (1950). Silage capacity was determined by taking measurements with a pH meter. Lactic acid and the amount of ammonia-N were measured with colorimetry in water extracts of fresh silage, using Madrid *et al.* (1999a) and Chaney and Marbach (1962) methods, respectively. The level of volatile fatty acids was determined in water extracts of fresh silage by capillary gas chromatography, according to the method described by Madrid *et al.* (1999b).

Also, multiresidues (insecticides, herbicides, bactericides and fungicides) were studied in artichoke by-products, at days 0, 4, 12 and 50. Multiresidues studied were: diazinon, chlorpyrifos methyl, fenitrothion, quinalphos, prometryn, myclobutanil, penconazole, pendimethalin, triadimefon. The levels of these multiresidues were determined by gas chromatography with electron capture detector (ECD) or nitrogen-phosphorus detector (NPD), according to the methods described by Oliva *et al.* (2000) and Navarro *et al.* (2000).

Analyses of variance were performed following the procedures described by Steel and Torrie (1980) for comparison between effects of the ensiling days on fermentative and chemical values.

Results and discussion

Table 1 shows the chemical and fermentative composition of the raw materials of artichoke by-products for 50 days of ensiling. The artichoke by-product showed good aptitude to ensiling; pleasant smell and good visual characteristics were obtained. In this sense, the conserved process does not show significant differences in pH (4.64) after 12 days of ensiling until the end of the process. Values of pH obtained in our study classified the silage as good quality for silages with 30% of DM, according to recommendations based on DM content suggested by Keady and Murphy (1998). The low pH, which is usually accomplished through the fermentation of sugars in the crop to lactic acid by lactic acid bacteria, decreases plant enzyme activity and prevents the proliferation of clostridia and enterobacteria (Woolford, 1984).

During the silage process, the artichoke by-product produces a steady increase in lactic acid concentration during the first 12-24 days (2.69% and 3.15% on dry matter). Diminishing until it reaches 1.98% at the end of the experiment. The values obtained remain within the lowest limit considered as very best for good silage, according to Catchpole and Henzell (1971) and McDonald *et al*. (1991). Lactic acid is the most effective acid for reducing silage pH, thereby conserving high quality forage. Ensiled forages with the highest lactic acid concentrations tend to be more nutrient dense, more palatable and sweet smelling, which results in greater nutrient intake.

Table 1. Fermentative and chemical composition (%DM) of artichoke by-product for 50 ensiling days

	Day									SE	Significance level
	0	1	2	3	4	8	12	24	50		
Temperature (ºC)	-	26.5	25.2	26.0	25.5	25.5	26.2	25.5	26.5	0.54	NS
pH	5.84^{cd}	6.12^{d}	5.76^{cd}	6.31^{d}	5.44^{bc}	4.96^{ab}	4.64^{a}	4.55^{a}	4.11^{a}	0.35	***
Lactic acid	0.00^{a}	0.01^{a}	0.04^{a}	0.04^{a}	0.00^{a}	0.48^{b}	2.69^{d}	3.15^{e}	1.98^{c}	0.15	***
VFA	0.73^{ab}	1.08^{ab}	0.76^{ab}	0.51^{a}	1.00^{ab}	1.36^{b}	1.29^{b}	2.07^{c}	1.46^{b}	0.58	**
Ammonia-N	0.02^{a}	0.04^{b}	0.04^{b}	0.05^{b}	0.04^{b}	0.06^{cd}	0.06^{c}	0.07^{d}	0.08^{e}	0.00	***
WSC	5.61^{c}	1.32^{a}	1.40^{a}	1.98^{a}	2.21^{a}	2.53^{ab}	2.32^{ab}	3.70^{bc}	1.12^{a}	1.21	***
DM	29.7^{d}	27.6^{cd}	26.1^{abc}	26.4^{bc}	26.9^{bc}	24.3^{a}	25.5^{ab}	27.5^{cd}	25.8^{abc}	1.57	**
Ash	5.77	4.96	5.25	5.98	5.32	5.93	4.93	5.03	4.85	0.74	NS
CP	10.1^{abc}	9.8^{ab}	10.1^{bc}	10.2^{bc}	9.2^{ab}	9.6^{ab}	9.8^{ab}	11.0^{c}	8.8^{a}	0.87	**

^{ab}Means in the same row with different superscripts letters are significantly different.
**P<0.01; ***P<0.001; NS = not significant.

Total volatile fatty acid (VFA) concentration was different (P<0.01) between control days of silage. The general tendency was increased to 24 days, the highest level being of 2.07 (%DM) at this time. In any case, the VFA concentration was lower than lactic acid concentration, as recommended by Catchpole and Henzel (1971). High VFA levels imply a slow or prolonged fermentation, excessive loss of energy and loss dry matter intake (McDonald *et al*., 1991). So, volatile fatty acids should be present only in properly fermented silage.

Dry matter underwent light fluctuations during the period under study. Effluents were not detected during the ensiling of the artichoke by-product. The material used in the experiment has high initial dry matter (29.8%), which is in agreement with Hardy (1980) and Amella *et al.* (1982) who indicated that the percentage of dry matter in vegetal crops used for silage should be 25-30%, which increases to 35-40% when tower silos are used.

In addition, our silage with artichoke by-product had a level of ammonia-N lower than 7% of total nitrogen, in all days of control. This result indicated that our silage was of good quality, because protein degradation was low. De Haro *et al.* (2001) reported poor quality silage when ammonia-N was greater than 7% of total nitrogen.

The evaluated by-product did not show multiresidues (Table 2), at least of the valued substances, except for prometryn. This residue is an organic-herbicide. The level found at day 0 was 0.04 ppm, and this value decreased to 0.01 ppm at day 4 of ensiling. However, this concentration falls down and disappears completely after 12 days of ensiling. In addition, the prometryn concentration was lower than the maximum residue limit (MRL) at any time.

Table 2. Multiresidues studied in artichoke by-products after 50 days in microsilos

Multiresidues	Type	MRL (ppm)*	Retention time (minutes)	Day 0	Day 4	Day 12	Day 50
Diazinon	Organicphosphoric-insecticide	0.02	15.58	ND**	ND	ND	ND
Chlorpyrifos methyl	Organicphosphoric-insecticide	0.05	17.98	ND	ND	ND	ND
Fenitrothion	Organicphosphoric-insecticide	0.50	19.87	ND	ND	ND	ND
Quinalphos	Organicphosphoric-insecticide	0.05	24.55	ND	ND	ND	ND
Prometryn	Organic-herbicide	0.10	18.67	0.04	0.01	ND	ND
Myclobutanil	Bactericidal-fungicide	1.00	30.53	ND	ND	ND	ND
Penconazole	Bactericidal-fungicide	0.20	27.63	ND	ND	ND	ND
Pendimethalin	Organic-herbicide	0.05	27.17	ND	ND	ND	ND
Triadimefon	Bactericidal-fungicide	0.05	26.09	ND	ND	ND	ND

*MRL: Maximum residue limit; **ND: Not detected.

Conclusions

Fresh artichoke by-product showed good aptitude to be ensiled and acceptable chemical composition. No multiresidues have been found after 12 days of ensiling. It can also be concluded that the evaluated by-product can be used after their ensilage and without health risk in ruminant feeding.

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