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Chemical composition, *in vitro* digestibility and fermentation kinetics of arboricultural and agro-industrial by-products in the north of Morocco

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Abstract. Main agricultural by-products in the North of Morocco were evaluated for chemical composition, phenolic compounds, in vitro dry and organic matter digestibility (IVDMD, IVOMD), fermentation kinetics, microbial biomass production (MBP) and partitioning factor (PF). Olive by-products contained highest crude protein (CP), ether extract (EE), ADL and NDF contents (69.8, 178, 526and 691 g/kg DM, respectively). Cactus cladodes of the season (YC), destoned olive cake (OC) preserved by silage (EOC) and OC obtained from olive oil extraction by three-phase centrifugation (EC3P) presented the highest IVDMD (84.10, 69.8 and 65. 1, respectively). However, EC3P and EOC promoted more MBP than YC (395 and 341 vs 122 mg/g DM incubated, respectively), and showed good PF (4.39 and 5.02 mg IVOMD/ml gas, respectively). Fig leaves (FL) showed the lowest MBP (30.3 mg/g of DM incubated) because of its low protein and energy content. Among studied by-products, EOC could be beneficial for ruminant feed, while YC could be an interesting minerals source.

Keywords. By-products – Chemical composition – *In vitro* gas production – *In vitro* digestibility.

Composition chimique, digestibilité* in vitro *et cinétique de fermentation des sous-produits de l'arboriculture et de l'agro-industrie du nord du Maroc

Résumé. *Les principaux sous-produits de l'agriculture du nord du Maroc sont évalués en termes de composition chimique, composés phénoliques, digestibilité* in vitro *de la matière sèche et matière organique (IVDMD, IVOMD), cinétique de fermentation, biomasse microbienne (MBP) et facteur de partition (PF). Les sous-produits d'olivier contiennent la teneur la plus élevée en protéine (CP), extrait éthéré (EE), ADL et NDF (69,8, 178, 526 et 691 g/kg MS, respectivement). Les jeunes raquettes de cactus (YC), les grignons d'olive dénoyautés et ensilés (EOC) et ceux obtenus par centrifugation à 3 phases (EC3P) ont montré une IVDMD élevée (84,1, 69,8 et 65,1, respectivement). Cependant, EC3P et EOC favorisent plus de MBP que YC (395 et 341* vs *122 mg/g de MS incubée, respectivement), et montrent un bon PF (4,39 et 5,02 mg IVOMD/ml gaz, respectivement). Les feuilles de figuier (FL) qui contiennent moins de protéines et d'énergie, ont présenté des MBP faibles (30,3 mg/g de MS incubée). Parmi les sous-produits étudiés, EOC est plus recommandable pour l'alimentation des ruminants, alors que YC constitue une source intéressante de minéraux.*

Mots-clés. *Sous-produits – Composition chimique – Production de gaz – Digestibilité* in vitro*.*

I – Introduction

In the northern region of Morocco, agricultural by-products are largely available. Several studies showed the possibility of exploiting agricultural by-products as alternative feed resources (Makkar, 2003; Ben Salem and Smith, 2008). However, by-products are not yet extensively used because of lacking information on their nutritional value. Chemical analysis, particularly in vitro digestibility can help in the preliminary evaluation of by-products nutritive value in order to identify the suitable feeds (nutrient content and digestibility) for livestock. The objective of this study was to assess the potential nutritive value of main agricultural by-products based on their chemical composition, and in vitro gas production kinetics.

II – Materials and methods

This work has concerned olive leaves (*Olea europaea,*OL), fig leaves (*Ficus carica,*FL) and cactus (*Opuntia ficus indica*) cladodes of the season (YC) and mature (MC), destoned olive cake (OC) obtained from mechanical pressure (EMP), two-phase (EC2P), three-phases (EC3P) centrifugation extraction procedures of olive oil, and destoned olive cake preserved by silage (EOC). By-products were oven-dried (60℃) and milled using a 1-mm sieve for their later chemical, in vitro digestibility and kinetics analysis.

Dry matter (DM) was determined by drying at 135°C for 4 h (AOAC, 1997). Crude protein (CP) content was determined using the Kjeldahl method (AOAC, 1997). Ether extract (EE) was determined using di-ethylic ether extraction in a Soxhlet system (AOAC, 1997). Ash content was obtained after incineration at 600℃ for 8 hours (AOAC, 1997). The NDF, ADF and ADL were determined using fiber extractor (FiberTech) as described by Van Soest *et al.* (1991).

Fermentation kinetics and in vitro digestibility were estimated by the in vitro method of Menke and Steingass (1989). The rumen fluid used for incubation was taken from three slaughtered goats grazing on forest pasture. The inoculum was prepared as described by Goering and Van Soest (1975). The volume of gas was recorded at 0, 2, 4, 8, 12, 24, 48, 62 and 72 hours of incubation using 100 ml gradual glass syringe plunger. At the end of the incubation, contents of each syringe were used to estimate the potential in vitro dry matter (DM) and organic matter (OM) disappearance (IVDMD and IVOMD, respectively). In order to estimate parameters of gas production kinetics, data of the cumulative gas volume produced was fitted to the exponential equation $P=a+b(1-e^{-ct})$ (Ørskov and Mc Donald, 1979), where P (ml) represents the cumulative gas volume at time t; “a” the gas production from soluble fraction; “b” the gas production from insoluble fraction; “a+b”: the potential gas production and, “c”: the constant rate of gas production during incubation. Microbial biomass production MBP (mg/g of incubated DM) = IVOMD - (Vgas x SF) is measured according to Blümmel (2000); where Vgas is the gas volume produced in ml per g of DM, and (SF) is the stoichiometric factor. The partitioning factor at 24 h of incubation (PF24; a measure of fermentation efficiency) was calculated as the ratio of truly degraded substrate in vitro (mg) to the volume of gas (ml) produced at 24 h (Blümmel *et al.,* 1997).

The in vitro gas production parameters (a, b and c) were estimated using Proc NLIN (SAS, 2002). Data on chemical composition, in vitro digestibility parameters (IVDMD, IVOMD, MBP and PF), gas volume production at time t, in vitro gas production constants (a, b, a+b, c) were subjected to analysis in completely randomized design using GLM procedure (SAS, 2002). Differences between mean values were tested using LSD’s test.

III – Results and discussion

1. Chemical Composition

Olive by-products, in particular OC, contain the highest rate of CP (60.4 to 69.8 g/kg DM), ether extract (113 to 178 g/kg DM) and dry matter (519 to 731 g/kg DM). Parietal constituents (ADF, ADL and NDF) are more presented in olive by-products contrary to FL and cactus cladodes (Table 1). Centrifugation mode of oil extraction gets more EE than mechanical pressure (177 and 157 g/kg *vs* 114 g/kg DM), but accuses more ash losses (31.6 and 35.3 *vs* 85.9 g/kg DM, respectively for EC3P, EC2P and EMP). However, this technique seems to give an olive cake with more content of lignin (456 and 526 vs 251 g/kg, respectively for EC2P, EC3P, EMP). Among all by-products, the highest contents of parietal components were obtained in the olive residues particularly EC3P (691; 526 and 519 g/kg DM, respectively for NDF, ADF and ADL). The FL have less lignin than OL (230 vs 377 g/kg DM), but the cactus cladodes showed the lowest content in lignin among all by-products (114 g/kg DM).

Table 1. Chemical composition of by-products (g/kg DM)

By-products	DM	CP	EE	Ash	ADF	ADL	NDF
OC EMP	731[a]	60.4[c]	114[c]	85.9[d]	477[b]	251[e]	604[b]
OC EC2P	652[b]	69.8[a]	157[b]	35.3[f]	450[c]	456[b]	579[c]
OC EC3P	573[c]	64.6[b]	178[a]	31.6[f]	519[a]	526[a]	691[a]
Ensiled OC	519[d]	67.0[ab]	113[c]	94.9[c]	229[e]	344[d]	620[b]
Olive leaves	571[c]	56.8[c]	89.5[d]	63.3[e]	378[d]	377[c]	419[d]
Mature cladodes	52.6[f]	29.8[e]	18.9[e]	129[a]	148[f]	149[g]	341[f]
Young cladodes	47.9[f]	48.6[d]	29.5[e]	110[b]	112[g]	113[h]	355[ef]
Fig leaves	296[e]	35.5[de]	61.8[d]	92.8[cd]	229[e]	230[f]	362[e]
SEM	8.73	1.45	6.95	1.21	2.85	0.18	0.25

Among studied by-products, olive cake obtained by centrifugation has interesting protein and energy values. But, nutritive value of by-products is globally low. In fact, total protein content not exceed 70 g/kg DM. However, ether extract reached 177 g/kg DM. Martín García *et al.* (2003) reported similar CP contents of OC (72.6 g/kg DM) but with lower EE contents (54,5 g/kg DM). Also, lower EE content of OL (56.4 g/kg DM) have been obtained by Molina *et al*. (2003b). Molina and Yáñez-Ruiz (2008) explained that the variation in composition depends on the plant variety, climatic conditions and moisture content. Also, variable amounts in EE depend mainly on residual oil that comes from the crushing of olives during cleaning prior to oil extraction. The NDF and ADF levels are similar to those reported by Martín García *et al.* (2003), Molina *et al.* (2003b), and Al-Masri (2003) with 676 and 406 g NDF/kg DM, 544 and 302g ADF/kg DM, respectively for OC and OL. However, the lignin content of OC (289 g/kg DM) and OL (199 g/ kg DM) reported by these authors are largely lower than ours values. In fact, cell wall constituents vary widely depending on the proportion of stones in OC. Rodriguez-Filex and Cantwell (1988) reported lower contents in CP, EE and ash of cactus cladodes (10.1, 2, and 13 g/kg DM, respectively). Soil and climatic conditions of the cactus plantation and mainly the *Opuntia* species, may be the cause of this difference.

2. Degradation kinetics and in vitro digestibility

During the first 12 hours of incubation, gas production has been quicker and reaches an asymptotic speed faster with fig and cactus by-products than olive by-products (Fig. 1). In fact, FL and YC produce more fermentation gas in a shorter time than olive by-products (Fig.1). Within the OC, ensiled olive cake (EOC) is the by-product which presents more gas production. The highest digestibility is recorded with YC, EOC and EC3P (84.1%, 69.8% and 65.0% respectively; Table 2). In fact, compared to others OC, EOC promoted the highest MBP (395 mg/g of incubated DM) with good fermentation efficiency (PF: 5.02) and presents satisfactory degradation rate (0.15 h^{-1}) of the insoluble fraction. Also, high degradability has been obtained with YC and OL (0.15 and 0.15 h^{-1}). But, these resources did not promote good microbial biomass production (122 and 154 mg, respectively) and showed low fermentation efficiency (3.23 and 3.30 mg IVOMD/ml gas, respectively) than EOC.

Globally, digestibility of most studied by-products is low, except for cactus cladodes. The Anti-nutritionals substances, especially lignin, and also the low content in protein and energy which influence microbial proliferation in rumen, cause digestibility decrease. EOC, which contains less lignin and NDF, has the highest digestibility coefficient among olive by-products. Indeed, ensiled olive cake (EOC) shows good fermentation at 72 h producing a high amount of gas. Bendaou (2003) explains that the pre-degradation in cell walls during silage fermentation facilitates micro-organisms access in the rumen contents cell, which improves the digestibility. Therefore, EOC shows clearly a nutritional advantage. Vaccarino *et al.* (1982) obtained with stoned OC very low in vitro digestibility values of dry and organic matter (15.8% and 9.7%). This difference is due to the oil extraction mode and preservation by silage. However, Molina *et al.* (2003a) obtained, with using goats juice, similar values of in vitro dry and organic matter digestibility (49% and 46%, respectively). Delgado Pertiñez *et al.* (2000), Martín García *et al*. (2003) and Molina *et al. (*2003a) reported similar in vitro dry matter digestibility of OL (46%).

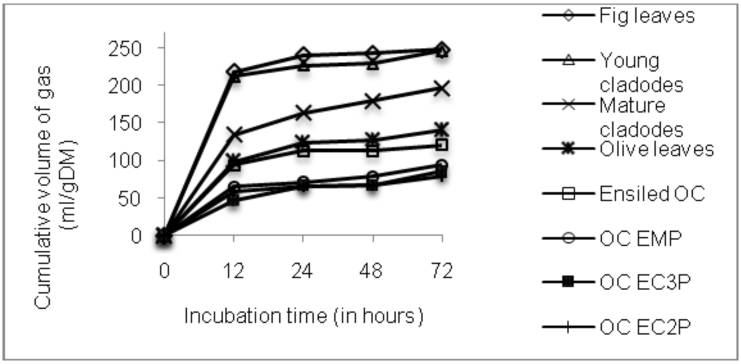

Fig. 1. Cumulative gas production (ml/g DM) of by-products at different incubation times.

Young cactus cladodes present some satisfactory nutritive parameters. Nevertheless, their forage use requires necessarily protein and energy supplementation to improve its MBP. In fact, the low microbial production observed with cactus cladodes may due to the poor quality feeds specially lack of soluble carbohydrates in cladodes which decrease protozoa concentrations in the rumen (cited in Molina and Yáñez Ruiz (2008).

Table 2. In vitro digestibility (%), microbial biomass production (mg), the partitioning factor (PF, in mg IVOMD/ml gas 24h) of by-products and dry matter degradation constants (a,b,c)

By-Product	IVDMD	IVOMD	MBP	PF	a	b	c	a+b
OC EMP	48.4^{f}	41.4^{ef}	206^{d}	4.3^{b}	6.20^{dc}	76.5^{e}	0.14^{ab}	82.7^{d}
OC EC2P	35.1^{g}	38.8^{f}	215^{cd}	4.3^{b}	3.35^{d}	67.8^{e}	0.17^{a}	71.2^{d}
OC EC3P	65.0^{c}	58.3^{cd}	341^{b}	4.9^{ab}	6.61^{c}	75.1^{e}	0.08^{b}	81.7^{d}
Ensiled OC	69.8^{b}	60.7^{c}	395^{a}	5.0^{a}	13.3^{a}	119^{d}	0.15^{ab}	132^{c}
Olive leaves	46.7^{f}	46.2^{e}	154^{e}	3.3^{c}	11.2^{ab}	120^{d}	0.14^{ab}	131^{c}
Mature cladodes	83.6^{a}	63.4^{b}	202^{d}	2.7^{d}	13.9^{a}	167^{c}	0.13^{b}	181^{b}
Young cladodes	84.1^{a}	66.5^{a}	122^{e}	3.2^{c}	8.36^{bc}	229^{b}	0.15^{ab}	237^{a}
Fig leaves	62.3^{d}	57.5^{d}	30.3^{f}	2.3^{d}	-1.01^{e}	251^{a}	0.12^{b}	250^{a}
SEM	0.20	0.20	0.02	0.02	1.02	5.73	0.01	6.12

$^{a-g}$ Means within the same column with different superscript are significantly different (P<0.05).
SEM: standard error of the mean.

IV – Conclusions

The studied by-products constitute a source of medium-to-low quality feed. On the basis of their nutritives parameters, olive cake EC3P especially when it is ensiled is better classified as a local food resource. However, the improvement of their effective digestibility is necessary by mean of totally stoning and increasing protein value. Considering their satisfactory in vitro digestibility and minerals contents, young cactus cladodes could fill the mineral deficiency in the ruminant diet. However, to optimize by-products use in ruminant diet, their anti-nutritional composition has to be identified.

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