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NUTRITIVE VALUE OF CO-PRODUCTS DERIVED FROM OLIVECAKE IN RABBIT FEEDING

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Abstract: Olive cake is one of the main agro-industrial co-products in the Mediterranean area of Spain, with high availability almost all year round. In addition, most of the product is dehydrated, which increases its interest in monogastric species such as rabbits. Nineteen samples from various Spanish oil mills using different processing methods were analysed for their chemical composition and *in vitro* digestibility. The average composition was [in dry matter (DM) basis]: ash (9.64%), neutral detergent fibre (52.0%), acid detergent fibre (36.8%), acid detergent lignin (19.1%), crude protein (CP) (11.3%), insoluble neutral (8.0%) and acid detergent crude protein (5.15%), ether extract (10.9%) and gross energy (21.9 MJ/kg). DM and CP *in vitro* digestibility were, on av., 53.4 and 41.4% respectively. High variability was observed among the samples for most of the traits studied. Fibrous fractions were highly correlated among them and negatively with ether extract content, whereas CP was little related to other feed components. A stepwise regression analysis allowed us to determine regression equations to predict DM and CP *in vitro* digestibilities from chemical composition (R^2=0.80 and 0.91, respectively). As regards the current results, olive cake has a potential use for rabbits as a source of insoluble fibre and lignin. Crude samples (not oil extracted) combined with sieving to retain the smaller particles have an additional interest, because of their higher energy value and significant supply of high quality fat.

Key Words: olive cake, processing, nutritive value, rabbits.

INTRODUCTION

For the agri-food industry, the use of its co-products into animal feed represents a mean of nutrient recycling and should be considered as a priority way of by-product elimination. Accordingly, the use of agro-industrial co-products can be expected to have a positive economic impact and a reduction of the environmental burden.

Olive cake (OC) is a by-product of olive oil manufacturing. The pomace produced in mills contains between 18 and 32% of stones (Nefzaoui, 1979). Stones are usually separated to be used as biomass for their high value for this purpose. Crude OC contains a significant amount of oil that can be extracted totally (exhausted, EOC) with hexane. EOC is currently the most common oil co-product marketed in Spain, mostly being used as biofuel. A small part is utilised in the form of dark coloured granules for feeding ruminants bred in extensive systems.

The final yield in the process is 25-40 kg of crude OC per 100 kg of olives (Eraso *et al.*, 1978), which means a potential production in Spain of around 2 million tonnes per year of EOC dehydrated. On some occasions, OC can be marketed crude or partially oil-extracted using physical methods. In either case, previous dehydration of the product is required. Dehydration is performed using different procedures which vary in terms of the applied temperature and drying time. The traditional method is by drying drum powered by gases from the combustion of EOC. Some industries have implemented a new method of drying using exhaust gases from engines and turbines (cogeneration). There are

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also methods of drying by using superheated steam, although they have not been tested on an industrial scale yet. Before its dehydration, the product remains for a variable time (0-8 mo) in storage ponds.

The chemical composition of OC varies widely according to the characteristics of the olive, the climate and the manufacturing process used. These factors determine changes in the proportion of its different constituents (pericarp, mesocarp, endocarp, and remains of stones) that greatly differ in their chemical compositions (Eraso *et al.*, 1978; Nefzaoui, 1991). According to consulted databases (CIHEAM, 1990; FEDNA, 2010; SIA, 2015 and FEEDIPEDIA, 2015), EOC without stones is characterised by a high proportion of the fibrous fraction (highly lignified) and a significant content of protein (about 10%) with a high proportion linked to fibre, and then a low nutritive value for most animal species. Crude olive cake, however, has a significant concentration of high quality oil [between 8 and 16% on dry matter (DM)], with a high proportion of oleic acid.

Rabbit diets can include a significant amount of olive oil co-products, because of the high requirements of insoluble fibre in this species and the advantages of a dietary supplementation with high quality fat (De Blas and Mateos, 2010). The aim of the current study was to evaluate the potential nutritive value for rabbits of traditional and new olive oil co-products obtained using different manufacturing procedures.

MATERIAL AND METHODS

Samples

A total of 19 samples of olive cake were surveyed from 3 Spanish plants that used a 2-phase centrifugation process. The origin and processing methods used are listed in Table 1. Samples studied include crude (n=12), partially (n=3), and totally (n=4) oil-extracted olive cakes. Stones from the OC were totally (n=14) or partially (n=5) removed. The coarser particle size (>1 mm) of 5 of the samples was sieved and removed. Drying temperature ranged from 71 to 120°C.

Chemical analysis

Procedures from AOAC (2000) were used to determine DM (934.01), ash (942.05) and ether extract (920.39). Total N was measured by combustion (method 986.06; AOAC, 2000) using a Leco equipment (model FP-528, Leco

Table 1: Description of origin and processing of olive-cake co-products studied.

Sample No.	Production plant	Oil content	Stones	Dehydration process	Temperature °C	Sieving
1	Puente Genil	crude	removed	cogeneration	85-90	no
2	Puente Genil	crude	partially removed	steam	110	no
3	Puente Genil	extracted	removed	cogeneration	85-90	no
4	Puente Genil	extracted	partially removed	steam	110	no
5	Puente Genil	crude	removed	cogeneration	86	no
6	Puente Genil	crude	removed	cogeneration	106	no
7	Puente Genil	crude	removed	cogeneration	120	no
8	Puente Genil	crude	removed	cogeneration	85	no
9	Puente Genil	extracted	removed	cogeneration	85	no
10	Puente Genil	crude	removed	cogeneration	71	no
11	Puente Genil	crude	removed	cogeneration	71	yes
12	Puente Genil	partially extracted	partially removed	cogeneration	NA	no
13	Puente Genil	extracted	removed	cogeneration	71	no
14	Linares	partially extracted	partially removed	cogeneration	78	no
15	Linares	partially extracted	partially removed	cogeneration	78	yes
16	Puente Genil	crude	removed	cogeneration	78	no
17	Antequera	crude	Removed	cogeneration	NA	yes
18	Antequera	crude	Removed	cogeneration	NA	yes
19	Antequera	crude	Removed	cogeneration	NA	yes

NA: Not available

Corporation, St. Joseph, MI, USA) and crude protein (CP) estimated as N content×6.25. Concentration of neutral detergent fibre, acid detergent fibre and acid detergent lignin (NDF, ADF and ADL, respectively) were determined sequentially using the filter bag system (Ankom Technology Corp., Macedon, NY, USA) according to Mertens (2002), AOAC (2000; procedure 973.187) and Van Soest *et al.* (1991), using heat stable amylase (A3306, Sigma-Aldrich, Tres Cantos, Spain), and expressed without residual ash. The contents in hemicelluloses and cellulose were estimated from the differences between NDF–ADF and ADF–ADL concentrations, respectively. The proportion of neutral and acid detergent insoluble CP (NDICP and ADICP, respectively) was determined following the standardised procedures of Licitra *et al.* (1996), by analysing the N content (combustion method) in the NDF and ADF residues, respectively. Gross energy concentration was measured in an isoperibol bomb calorimeter (Parr 1356, Parr Instruments Co., Moline, IL, USA).

In vitro *analysis*

In vitro analysis was performed following the method proposed by Ramos *et al.* (1992) and Boisen (1991) using ANKOM bags as modified by Abad *et al.* (2013) to determine *in vitro* DM and CP digestibility in rabbits. Samples, previously ground at 1 mm pore size, were weighed (0.5 g) into filter bags (Ankom Technology Corp., Macedon, NY, USA) and placed in a Daisy II incubator jar (3.5 L and 30 filter bags/jar). A magnetic rod, 25 mL of phosphate buffer (0.1 M, pH 6.0) and 10 mL of 0.2 M HCl solution were added for each bag (750 mL of phosphate buffer and 300 mL of HCl solution for each jar with 30 bags). The solutions were mixed carefully by gentle magnetic stirring. The pH was measured and then adjusted to pH 2 with 1 M HCl or 1 M OHNa solutions. Then, a 1 mL/bag (30 mL/jar) of fresh pepsin solution [25 mg of pepsin (pepsin from porcine, 2000 FIP-Units/g protein, Merck n 7190)/mL 0.2 M HCl] was added and mixed. The jar was closed and the samples incubated in an oven at 40°C for 1.5 h. After this incubation, 10 mL/bag (300 mL/jar) of phosphate buffer (0.2 M, pH 6.8) and 5 mL/bag (150 ml/jar) of 0.6 M OHNa solution was added. After mixing, the pH was adjusted to 6.8 adding 1 M HCl or 1 M OHNa solutions. Afterwards, 1 mL/bag (30 ml/jar) of fresh pancreatin solution [100 mg of pancreatin (pancreatin from porcine, grade VI, Sigma n 1750)/mL phosphate buffer pH 6.8] was added, the jar closed and the samples incubated at 40°C for 3.5 h. After the second incubation, the pH was adjusted to 4.8 by adding acetic acid and then 0.5 mL/bag (15 mL/jar) of Viscozyme (Viscozyme 120 L, 120 FBG/G, Novo Nordish) was added, mixed and incubated at 40°C for 16 h. The entire soluble residue was then eliminated and the bags were washed in the jar with water at 40°C three times and mixed carefully (the first one for 30 min at 40°C with agitation in the incubator), followed by rinsing with ethanol and acetone to prevent adherence of any residue in the bags. Finally, the bags were dried at 103°C for 24 h. Two bags without any sample were used as blanks in each jar. *In vitro* DM digestibility (DMd_{inv}) was calculated as:

$$DMd_{inv} = 1 - \frac{W_3 - (W_1 \times C_1)}{W_2}$$

where W_1 is the bag tare weight, W_2 is the dry sample weight, W_3 is the final oven dry weight of the bag after digestive process and C_1 is the blank bag correction (final oven dry weight of the blank bag after digestion/original blank bag weight). Additionally, in the dry residual the CP concentration was measured to determine the *in vitro* CP digestibility (CPd_{inv}).

Statistical analysis

A correlation procedure (SAS Inst. Inc., Cary, NC) among chemical variables, *in vitro* analysis and predicted nutritional value was performed. A stepwise regression analysis was used to predict the *in vitro* digestibility from the chemical composition, using PROC REG of SAS (2008). The stepwise procedure only introduced variables in the model when they contributed to a significant improvement ($P<0.05$) in the estimation of the dependent variable.

RESULTS

The chemical composition and *in vitro* digestibility of the 19 samples studied are shown in Table 2. Their average composition per oil content and presence of stones are illustrated in Table 3. The mean values per each analytical trait and its variability (expressed from its standard deviation and range) are presented in Table 4 and the correlation matrix among the traits measured in Table 5.

Table 2: Chemical composition (% DM) and *in vitro* digestibility (%) of olive-cake co-products studied.

Sample No.	Ash	CP	EE	NDF	ADF	ADL	NDICP	ADICP	Gross Energy (MJ/kg DM)	DMd_{inv}	CPd_{inv}
1	10.0	11.0	11.3	43.9	30.3	16.6	6.48	3.76	23.0	61.2	48.8
2	10.2	10.4	12.5	46.4	31.8	17.0	6.10	3.53	22.4	50.1	49.3
3	13.6	13.2	ND	52.0	36.4	20.1	8.77	5.79	18.9	54.1	36.7
4	13.1	13.0	ND	56.2	39.8	22.3	8.11	5.05	18.9	42.5	38.6
5	7.8	11.6	14.4	52.0	37.4	19.2	8.13	ND	23.1	54.4	39.1
6	8.6	11.5	15.2	50.2	36.1	18.5	7.86	ND	23.2	55.0	41.2
7	8.5	10.8	15.7	50.1	34.4	17.8	6.68	ND	23.0	54.6	45.8
8	7.9	10.6	12.3	57.4	39.8	21.2	9.08	ND	22.9	56.1	35.7
9	9.0	11.7	0.0	65.1	44.5	22.7	9.52	ND	20.4	51.8	33.5
10	8.8	11.3	13.1	49.5	35.5	18.4	6.92	5.17	23.1	56.3	47.2
11	9.9	13.2	14.8	42.4	30.6	17.7	6.21	5.87	23.6	62.2	44.6
12	7.4	10.4	11.0	60.4	44.0	22.1	10.6	6.09	22.4	46.7	27.9
13	10.6	14.7	0.4	60.6	43.4	23.4	12.9	7.63	20.4	47.8	24.8
14	9.1	10.4	7.7	67.7	48.5	23.0	9.65	5.98	21.4	41.6	33.9
15	11.0	10.4	10.8	52.8	37.4	18.6	7.68	5.44	22.8	42.5	45.7
16	8.1	11.4	13.5	54.9	38.5	18.7	ND	ND	22.4	53.0	52.2
17	10.1	9.2	10.5	47.8	32.6	15.6	6.93	4.39	22.0	57.3	41.3
18	ND	9.0	12.0	37.4	26.9	15.0	5.11	3.46	20.0	66.6	60.6
19	ND	10.5	16.0	41.4	31.6	15.0	7.25	4.77	22.5	60.5	39.3

DM: dry matter. CP: crude protein. EE: ether extract. NDF: neutral detergent fibre. ADF: acid detergent fibre. ADL: acid detergent lignin. NDICP: neutral detergent insoluble crude protein. ADICP: acid detergent insoluble crude protein. DMd_{inv}:dry matter digestibility *in vitro.* CPd_{inv}*:* crude protein digestibility *in vitro.* ND: not determined.

As shown, the most important component in olive cake is NDF, with an average content of 52.0% on DM. It also presents a high standard deviation (SD=8.04) and a wide range (from 37.4 to 67.7%), mainly associated with the type of processing. In this way, higher values of NDF were obtained in EOC samples (58.5 as average±5.6% DM), whereas mean NDF concentration in samples sieved was lower (44.4±6.0% DM). The contents in other fibre fractions (ADF, ADL, hemicellulose and cellulose) were also relevant (averaging 36.8, 19.1, 15.2 and 17.7% DM, respectively); as shown in Table 5, they were highly and positively correlated with NDF (r values varying from 0.92 to 0.98). In particular,

Table 3: Average chemical composition (% DM) and *in vitro* digestibility (%) of samples stratified by oil content and presence of stone.

Oil content	Crude		Partially extracted	Extracted	
Stones	Partially removed	Removed	Partially removed	Partially removed	Removed
No.	1	11	3	1	3
Ash	10.2	8.9	9.2	13.1	11.1
Crude protein	10.4	10.9	10.4	13.0	13.2
Ether Extract	12.5	13.5	9.8	ND	0.2
Neutral detergent fibre	46.4	47.9	60.3	56.2	59.2
Acid detergent fibre	31.8	34.0	43.3	39.8	41.4
Acid detergent lignin	17.0	17.6	21.2	22.3	22.1
NDICP	6.1	7.1	9.3	8.1	10.4
ADICP	3.53	4.57	5.84	5.05	6.71
Gross Energy (MJ/kg DM)	22.4	22.6	22.2	18.9	19.9
DMd_{inv}	50.1	57.9	43.6	42.5	51.2
CPd_{inv}	49.3	45.1	35.8	38.6	31.7

DM: dry matter. No: number of samples used to obtain the mean value. NDICP: neutral detergent insoluble crude protein. ADICP: acid detergent insoluble crude protein. DMd_{inv}: dry matter digestibility *in vitro.* CPd_{inv}: crude protein digestibility *in vitro.* ND: Not determined.

Table 4: Chemical composition (% DM) and *in vitro* nutritional value (%) of 19 samples of olive cake.

	No	Mean	SD	Minimum	Maximum
Ash	17	9.6	3.5	7.4	13.6
Crude protein	19	11.3	1.4	9.0	14.7
Ether extract	16	10.9	5.8	0.0	15.7
NDF	19	52.0	8.0	37.4	67.7
ADF	19	36.8	5.6	26.9	48.5
ADL	19	19.1	2.7	15.0	23.4
Hemicellulose[1]	19	15.2	2.7	9.8	20.6
Cellulose[2]	19	17.7	3.3	11.9	25.5
ADL/NDF	19	0.369	0.023	0.326	0.417
NDICP[3]	18	8.0	2.6	5.1	12.9
ADICP[4]	13	5.15	2.64	3.46	7.63
Gross energy (MJ/kg DM)	19	21.9	1.5	18.9	23.6
DM digestibility *in vitro*	19	53.4	6.9	41.6	66.6
CP digestibility *in vitro*	19	41.4	8.6	24.8	60.6

DM: dry matter; SD: standard deviation; NDF: neutral detergent fibre; ADF: acid detergent fibre; ADL: acid detergent lignin; Hemicellulose=NDF–ADF; Cellulose=ADF–ADL; NDICP: neutral detergent insoluble crude protein; ADICP: acid detergent insoluble crude protein; CP: crude protein.

ADL concentration varied in parallel to that of NDF, with a degree of lignification of NDF close to 0.369 (CV=6.23%) in the overall population of samples studied.

Ether extract content had a high variability among samples (CV=53.1%), as it varied from values close to zero in exhausted OC up to 14.1% (±2.8%) on DM in crude OC, with intermediate determinations in partially extracted OC (9.82±1.9% DM). Instead, sieving seemed to be little related to this component in the current sample population.

Crude protein concentration in the OC group studied was relevant as it averaged 11.3% DM, with a relatively low CV (12.6%) among samples. Instead, the contents of NDICP and ADICP on DM varied widely (CV=32.4 and 51.3%, respectively), being highly and positively correlated with NDF level (r=0.82 and 0.70, respectively). The average proportions of NDCIP and ADICP in total CP were very high, averaging 0.708 and 0.456, respectively. The highest

Table 5: Correlation (Pearson´s coefficient) matrix among chemical composition and *in vitro* digestibility in 19 samples of olive cake.

	Ash	CP	EE	NDF	ADF	ADL	Hem	Cell	ADL/NDF	NDICP	ADICP	GE	DMd_{inv}
Ash													
CP	0.46												
EE	–0.33	–0.38											
NDF	–0.15	0.27	–0.69^{a}										
ADF	–0.17	0.29	–0.64^{a}	0.98^{a}									
ADL	0.04	0.53^{a}	–0.70^{a}	0.92^{a}	0.92^{a}								
Hem	–0.09	0.21	–0.71^{a}	0.93^{a}	0.86^{a}	0.83^{a}							
Cell	–0.31	0.06	–0.54^{a}	0.93^{a}	0.94^{a}	0.76^{a}	0.79^{a}						
ADL/NDF	0.18	0.22	0.40	–0.45	–0.40	–0.17	–0.53^{a}	–0.53^{a}					
NDICP	–0.05	0.50^{a}	–0.71^{a}	0.82^{a}	0.85^{a}	0.85^{a}	0.67^{a}	0.77^{a}	–0.17				
ADICP	–0.03	0.68^{a}	–0.63^{a}	0.70^{a}	0.74^{a}	0.78^{a}	0.53^{a}	0.62^{a}	–0.01	0.86^{a}			
GE	–0.71^{a}	–0.31	0.91^{a}	–0.26	–0.24	–0.38	–0.27^{a}	–0.10	0.13	–0.30	–0.14		
DMd_{inv}	–0.23	–0.22	0.46	–0.77^{a}	–0.77^{a}	–0.72^{a}	–0.69^{a}	–0.74^{a}	0.19	–0.59^{a}	–0.48	0.25	
CPd_{inv}	–0.02	–0.46^{a}	0.61^{a}	–0.72^{a}	–0.75^{a}	–0.76^{a}	–0.57^{a}	–0.67^{a}	0.07	–0.93^{a}	–0.84^{a}	0.21	0.52^{a}

CP: crude protein; EE: ether extract; NDF: neutral detergent fibre; ADF: acid detergent fibre; ADL: acid dtergetn lignin; Hem: hemicellulose=NDF–ADF; Cell: cellulose=ADF–ADL; NDICP: neutral detergent insoluble crude protein; ADICP: acid detergent insoluble crude protein; DMd_{inv}: dry matter digestibility *in vitro*; CPd_{inv}: crude protein digestibility *in vitro*. ^{a}Values are significant (P<0.05).

Table 6: Stepwise regression analysis for DMd_{inv}, CPd_{inv} and DE using chemical components (% DM) as predictors.

	No	Step	Regression equation[1]	R^2	RSD	*P*-value
DMd_{inv}	19	1	82.7 (±8.3) – 0.798 (±0.219) ADF	0.52	4.51	0.003
	19	2	106 (±14) –2.05 (±1.07) Ash –0.924 (±0.209) ADF	0.64	4.09	0.003
	19	3	159 (±22) –4.24 (±1.16) Ash –1.54 (±0.28) ADF –0.884 (±0.321) EE	0.80	3.23	<0.001
CPd_{inv}	18	1	70.9 (±2.9) –3.78 (±0.34) NDICP	0.91	2.55	<0.001

DMd_{inv}: dry matter digestibility *in vitro*; CPd_{inv}: crude protein digestibility *in vitro*; DE: digestibility energy; ADF: acid detergent fibre; EE: ether extract; NDICP: neutral detergent insoluble crude protein; No: number of data used to develop the different models;
[1] Value in parentheses are standard error.

and lowest values of NDICP were obtained for the groups of oil-extracted and sieved OC samples (0.745 and 0.644, as average), respectively. Type of processing was less related to ADICP content.

Gross energy content of the samples studied was relatively high (21.9 MJ/kg DM, on average), because of the relatively high concentration in ether extract and ADL.

Following variations in chemical composition, both DMd_{inv} and CPd_{inv} determinations showed a wide range in the group of OC analysed (from 41.6 to 66.6 and from 24.8 to 60.6%, respectively), being mainly correlated respectively with ADF and NDICP concentrations (r=0.77 and –0.93, see Table 5). A stepwise regression analysis additionally included ash and ether extract (EE) contents in the prediction of DMd_{inv}, to reach a final R^2 value of 0.80 (see Table 6). Consequently, the highest and lowest values of DMd_{inv} and CPd_{inv} were obtained for the groups of sieved-not extracted OC and the EOC samples (on av., 0.578 and 0.491 for DMd_{inv} and 0.463 and 0.334 for CPd_{inv}, respectively).

A regression equation from Villamide *et al.* (2009) was also used to estimate the digestible energy (DE) content for rabbits of the OC samples from their measured DMd_{inv} and EE concentration:

$$\text{DE (MJ/kg DM)}=-1.51+0.180\ DMd_{inv}\ (\%)+0.32\ \text{EE}\ (\%DM)$$

The calculated values averaged 11.6 MJ/kg DM with a range between 7.21 and 14.5 MJ/kg DM, the highest estimations again being obtained for the group of sieved-OC samples (13.9 MJ/kg DM on average) and the lowest for the EOC samples (7.50 MJ/kg DM).

DISCUSSION

The main characteristic of OC is its high concentration of insoluble fibre (NDF). This component is quite indigestible in most non-ruminant species, including rabbits (Wiseman *et al.*, 1992; De Blas *et al.*, 1992). However, the current recommendation in rabbit feeds (e.g. De Blas and Mateos, 2010) establishes a high minimal content of NDF (37.8 and 35.5% DM in fattening rabbits and breeding does, respectively) in order to attain high levels of feed intake and also to minimise digestive disorders (Gidenne *et al.*, 2010; De Blas *et al.*, 2012). In practice, this restriction leads to combined feeding of fibrous by-products with concentrate feeds that provide nutrients required for highly producing animals (De Blas, 2013).

Olive cake samples also had a high proportion of ADL. This component is beneficial for rabbits to maximise performance (Nicodemus *et al.*, 1999; García *et al.*, 2002). A protective effect of lignin in preventing digestive disorders has been also recognised (Perez *et al.*, 1994; Gidenne *et al.*, 2001). Accordingly, a minimal level of ADL (around 5.5% DM) has been recommended in diets for rabbits (De Blas and Mateos, 2010).

The high fibre and lignin content also implies low DE estimation in oil-extracted OC samples with respect to current recommendations (11.3 and 11.9 MJ/kg DM for fattening rabbits and breeding does, respectively; De Blas and Mateos, 2010). The use of crude OC combined with sieving can help address this problem, as those samples had a lower NDF content and a higher EE, and therefore a gross energy and DE concentration above average. Fat is well digested in rabbits (Maertens *et al.*, 1986; Santomá *et al.*, 1987) and allows increasing dietary energy concentration and feed efficiency. Furthermore, fat has an added value in nutrition of lactating rabbits because of its positive influence on intake, milk production and kit viability (Méndez *et al.*, 1986; Fraga *et al.*, 1989; Fernández-Carmona *et al.*, 2000). In addition, olive oil has a high proportion of oleic acid (70.3%) and low in saturated fatty acids (Joven *et al.*, 2014) that makes its inclusion of interest in order to increase its retention and improve the fat quality of meat, as shown in rabbits by Dal Bosco *et al.* (2012). Otherwise, a high fat content in the olive cake might lead to nutritional and technological problems that should be checked in future research in order to assess safe maximal inclusion limits. Preliminary results obtained with local breeds (Kadi *et al.*, 2004; Mehrez and Mousa, 2011) have shown that use of olive cake in fattening diets is safe up to dietary levels of 25%.

The main restraint to the use of OC products in rabbit feeding lies in its low crude protein content with respect to recommendations, especially those of breeding does (Xiccato, 1996 and Xiccato *et al.*, 2006). Moreover, *in vitro* protein digestibility was low in parallel to its high proportion of NDICP and ADICP. Otherwise, the contribution of caecotrophy to daily protein intake has not been measured, but it should be scarce in accordance to the low allowance of substrates for growth of caecal microbial in this feed (Garcia *et al.*, 2000).

All in all, although more information is required, OC constitutes a potentially valuable ingredient for rabbit feeds to meet the high requirements for insoluble fibre and lignin. Crude OC has an additional value as a source of vegetal fat and because of its relatively high energy value, especially if samples are sieved to reduce its mean particle size. Low crude protein seems to be the most limiting factor for feed formulation in rabbits. However, data from its use at different levels of inclusion in rabbit feeds are needed in order to check potential digestive disorders.

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