Cardoon (Cynara cardunculus L. var. altillis) seeds presscake: a natural by-product for pigs feeding

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ABSTRACT

The cardoon seeds presscake is a natural by-product resulting from the mechanical treatment of the cardoon plant seeds. The chemical composition suggests its possible use in animal nutrition due to the content of proteins, fibre, lipids and biologically active substances. The presscake studied contained 7.1% of fat, 26.8% of fibre, 23.9% of protein, 37.1% of nitrogen-free extract and a goodly phenolic content (13.36 mg GAE g⁻¹ DW). The major fatty acids were oleic (26.5%) and linoleic (58.4%), showing a high degree of unsaturation. This study evaluated for the first time the inclusion of the cardoon presscake in pigs’ diet. The effects of the dietary treatment on meat quality and fatty acids profile were assessed. The results indicate that the intramuscular fat (IMF) was higher in the untreated animals. The monounsaturated fatty acids (MUFAs) were lower in the IMF of the treated pigs, whereas the polyunsaturated fatty acids (PUFAs) were higher.

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1. Introduction

The cardoon seeds presscake is a natural by-product potentially usable in animal feeding as a font of protein, fibre and lipid component that remain after the mechanical pressing of the cardoon plant seeds (Genovese et al. 2016a; Cabiddu et al. 2019). Cynara cardunculus L. (var. altilis DC.) is a perennial plant of the Mediterranean region, belonging to the Asteraceae family (Raccuia et al. 2004). The above-ground biomass and seed yield are influenced by genotype, rainfall amount and distribution, crop age and plant density (Francaviglia et al. 2016; Toscano et al. 2016). In Sicily, the cardoon seed yield and oil content have been studied in relation to environment, plant density and genetic factors. The seed yields ranged from 0.6 to 2.8 Mg ha\(^{-1}\), and seed oil content ranged from 22.0 to 28.8% (seed oil mass fraction) across populations (Raccuia and Melilli 2007; Raccuia et al. 2012). The Cynara cardunculus L. can be used for various purposes (Maccarone et al. 1999; Curt et al. 2002) and, besides its use in energy and food production, it is also considered a font of bioactive substances that can be exploited in the pharmaceutical and nutraceutical industry (Curt et al. 2002; Genovese et al. 2016b; Pappalardo et al. 2020). The cardoon has antioxidant properties that can be useful to improve animal feed, being a product rich in valuable compounds such as flavonolignans, flavonoids and phenolic acids such as chlorogenic acid, cynarin and caffeoylquinic acid derivatives, luteolin, and derivatives (Raccuia et al. 2004; Genovese et al. 2020). Currently, there are no available studies regarding the inclusion of the cardoon seeds presscake for pigs feeding. In light of this, we speculated the opportunity to explore the use of this by-product as feed for pigs, considering the natural precious composition of the cardoon plant seeds. Pigs are potentially among the best agro-industrial co-products users, being able to exploit, enhance and transfer the precious nutritional components in their meats, due to their marked ability to convert food into noble proteins (Warner et al. 2018). The cardoon seeds presscake presents a fatty acids profile that shows a high unsaturation degree and a higher amount of precious fatty acids such as the oleic and linoleic acids (Genovese et al. 2016a). This study evaluated for the first time the effects of the inclusion of the cardoon seeds presscake in the diet of 54 crossbred Pietrain x Landrace barrows pigs throughout the fattening period. The effects on meat quality and fatty acids profile were evaluated. The 3% of cardoon seeds presscake was included in the diet, as a partial replacement of wheat middling and soybean oil. Due to the lack of studies addressed the use of cardoon seeds presscake on monogastric animals (i.e., pigs), we opted to not exceeds the 3% of integration, also considering the phenolic content of the by-product that could influence the palatability.

2. Results and discussion

The chemical composition of cardoon seeds presscake is shown in Table 4S, whereas the composition of amino acids, sulfur amino acids and tryptophan is shown in Table 5S. The fatty acids profile of cardoon seeds presscake (Table 6S) showed that unsaturated acids predominate over saturated ones. The main compound of extracted oil was linoleic acid (58.4%), followed by oleic acid (26.5%). Interestingly this composition of cardoon seeds presscake, characterized by a high unsaturation degree (86.1%), is
comparable to common oilseeds such as sunflower and soybean (Cicero et al. 2018; Rotondo et al. 2020). Furthermore, the cardoon presscake, in addition to a reasonable proportion of essential amino acids and a relevant fatty acids profile, contains a goodly total phenolic content (13.36 mg GAE g\(^{-1}\) DW), added value to be considered an animal feed. In the scientific literature, comparable characteristics and properties were reported for other natural products (Tardugno et al. 2018; Aghraz et al. 2020; Tardugno et al. 2020; Vella et al. 2020; Tardugno et al. 2021). Furthermore, other results regarding the utilization of natural products in a local Italian pig breed feeding were also reported (Zumbo et al. 2020). The inclusion of the cardoon presscake in pigs diet also influenced the \textit{in vitam} and post-mortem condition (Table 1S) of the treated animals (see supplementary materials).

Effects of the dietary treatment on physicochemical profile of \textit{Longissimus thoracis} (LT) muscle are reported in Table 2S. Regarding the physical characteristics of LT, the values of pH\(_{45}\) and pH\(_{24}\), Lightness (L\(*\)), Redness (a\(*\)), Yellowness (b\(*\)), cooking loss and shear force did not show significative differences between the control and the treated group (Table 2S). In the chemical composition of LT muscle, no differences for moisture, crude protein and crude ash were observed between the two groups, whereas the intramuscular fat (IMF) content was significantly higher in the control group (\(p < 0.05\)) (Table 2S). The effects of the dietary treatment on the fatty acids in the IMF are shown in Table 3S. Furthermore, no differences in saturated fatty acids (SFAs) class between the two groups were observed. Among the SFAs, only the stearic acid was different (\(p < 0.05\)), resulting to be higher in the treated animals. The monounsaturated fatty acid class (MUFA) was lower (\(p < 0.05\)) in the IMF of the treated pigs. In particular, the oleic acid was found higher in the control group, although it was not significant. In regard to polyunsaturated fatty acids (PUFAs), their sum was higher in the treated animals (\(p < 0.05\)). Among the individual PUFA, the inclusion of cardoon seeds presscake increased significantly (\(p < 0.05\)) the concentration in IMF of C18:2n6.

Regarding the physical and chemical composition of LT muscle (Table 2S), the inclusion of cardoon seeds presscake affected (\(p < 0.05\)) only the IMF, registering a lower value. This aspect could find an explanation by a lower lipogenic capacity in intramuscular adipose tissue, as proposed for backfat adipose tissue by Mourot and Kouba (1999). The pH measured at 45 min post-mortem in both groups was between 6.39 and 6.40 (Table 2S). These values were in the standard (6.4–6.5) considering that in the pale, soft and exudative meat condition, the pH is below 5.9 (Bowker et al. 2000; Warner et al. 2018). The final pH (24 h) of the carcasses was equal to 5.61 and 5.65 in the two groups (Table 2S), showing values in the range of 5.6–5.8. Indeed, at pH values higher than 5.8, a reduction in meat delicacy, as well as the possibility of maintaining good quality during cooling, was noticed. The meat showing a high final pH value can have a gummy structure, increased water-holding capacity and decreased specific taste (Pipek et al. 2003). The pH values recorded in the two groups were within the optimal range, highlighting meat with high quality and with excellent acidification. Furthermore, no significant differences regarding the colour variables were observed (Table 2S). Specifically, the values of colour variables were within the satisficing range for average consumer acceptance (Aaslyng et al. 2007; Moeller et al. 2010; Warner et al. 2018).
In regard to the cooking losses and tenderness, it was highlighted by Hocquette et al. (2010) that the IMF influenced in a positive manner the tenderness and the overall acceptability of meat in different species due to the lower levels of the IMF that lead to dry and less-tasty meat. In this study, even though the IMF was lower in the treated animals, no significant differences in the two groups for the tenderness were noticed (Table 2S). The fatty acid profile of meat has a relevant role in its quality, consumer acceptance and then in human health. The inclusion of cardoon seeds presscake affected the intramuscular lipidic profile and the quality indices of atherogenicity (AI) and thrombogenicity (TI) that were lower ($p < 0.05$) in the treated pigs (Table 3S). In particular, no significant differences in the SFA class were observed (Table 3S). Among the SFAs, only the stearic acid was significantly different ($p < 0.05$), resulting to be higher in treated animals (Table 3S). The MUFA class was lower ($p < 0.05$) in the IMF from treated pigs (Table 3S). The higher percentage of MUFAs in the control group is due to the higher amount of oleic acid in this group, even though it was not significantly different from the treated group (Table 3S). With regards to PUFAs, the sum of these fatty acids was higher ($p < 0.05$) in the treated pigs (Table 3S). In particular, among the individual PUFA (Table 3S) the inclusion of the presscake increased significantly ($p < 0.05$) the concentration in IMF of C18:2n6. Finally, regarding the quality indices AI and TI, Ulbricht and Southgate (1991) proposed them to evaluate the different health effects of the various fatty acids. These indices permit to perform a better characterization of the atherogenic and thrombogenic potential of a vegetable or animal food than a simple approach based on saturated fatty acids or the ratio of PUFAs/SFAs as indicated by Fehily et al. (1994). The results obtained in this study and correlated to the quality indices showed significant differences, indicating that the integration of the cardoon seeds presscake could induce beneficial effects on the quality of the IMF of the meat.

3. Experimental

Experimental details of this study are available online (see supplementary materials).

4. Conclusions

This study represents the first attempt to evaluate the integration of the cardoon seeds presscake as a possible feed for pigs. The results indicate that this natural by-product has considerable chemical-nutritive characteristics for the amino acids and fatty acids composition and goody polyphenol content, which confers its nutraceutical properties. The supplementation of cardoon seeds presscake also influenced the in vitam and post-mortem condition of the treated animals, inducing beneficial effects on the quality of the meat, such as the reduction of the IMF deposition and qualitative parameters as the fatty acids composition and the nutritional indices.

Ethical statement

The procedures for animal management and samples collection were performed according to the European guidelines (Directive 2010/63/EU) for the care and use of animals in research. The
research was approved by the Regional Department of Agriculture, Rural Development and Mediterranean Fisheries—Sicilian Region, Italy, n. 94750023262, prot. 110180.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Data Availability Statement

The data of this study are available from the corresponding author on reasonable request.

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