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Abstract

The effect of olive oil inclusion on the chemical and sensory characteristics in cabanossi made with ostrich and warthog meat was investigated. Ostrich meat from two cottonseed oilcake (CSOC) dietary inclusion levels (0% CSOC and 9% CSOC), and olive oil were included at three levels (0%, 1% and 2%) resulting in six treatments. The fat content in the cabanossi increased with increasing levels of oil inclusion but were all <10%, which allows it to be classified as a low fat meat product. Total monounsaturated fatty acids in the cabanossi increased whilst total saturated fatty acids and total polyunsaturated fatty acids decreased as olive oil increased. The 0% CSOC cabanossi had a lower fat and higher crude protein content. The inclusion of olive oil at 2% resulted in a cabanossi with increased tenderness, juiciness and cured red meat colour, all factors that appeal to the consumer, while the overall flavour descriptors were not adversely affected by the inclusion of olive oil.

Keywords	Processed meat product; olive oil; ostrich; warthog; chemical; fatty acid; sensory

Corresponding Author	Louwrens Hoffman
Corresponding Author's Institution	Stellenbosch University
Order of Authors	Louwrens Hoffman, Katryn Schoon, Monlee Rudman, Tertius Brand, Antonella Dalle Zotte, Marco Cullere
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02/02/2018

Dear Prof Hopkins

We would like to submit the following manuscript for possible publication in Meat Science: **Profile of cabanossi made with exotic meats and olive oil**.

In this manuscript we evaluate (chemical and sensory) the effect of making a semi dried sausage without any pork fat but rather by using olive oil thereby producing a more healthy product. The pig meat source was warthog meat.

The experimental outlay was a 2 ostrich meat sources x 3 olive oil levels with six replicates per treatment.

The authors all agree with the contents and we have not submitted it to any other journal.

Yours sincerely.

LC Hoffman
Distinguished Professor: Meat Science
DST/NRF South African Research Chair in Meat Science: Genomics to nutriomics
Department of Animal Sciences
Faculty of AgriSciences
lch@sun.ac.za

www0.sun.ac.za/sarchi

SARChI
MEAT SCIENCE
GENOMICS TO NUTRIOMICS

Departement Veekundige Wetenskappe
Privaatsak X1, Matieland 7602 Suid-Afrika
Tel. +27 21 808 4916/Faks. +27 21 808 4750
e-pos: us-anim@sun.ac.za

Department of Animal Sciences
Private Bag X1, Matieland 7602 South Africa
Tel. +27 21 8084916/Fax. +27 21 8084750
e-mail: us-anim@sun.ac.za

Highlights

Different levels of olive oil were used as fat source in making ostrich/warthog cabanossi.

MUFA in the cabanossi increased whilst SFA and PUFA decreased as olive oil increased.

Olive oil at 2% resulted in increased tenderness, juiciness and cured red meat colour

Overall flavour descriptors were not adversely affected by the inclusion of olive oil

PROFILE OF CABANOSSI MADE WITH EXOTIC MEATS AND OLIVE OIL

L. C. Hoffman[a], K. Schoon[a], M. Rudman[a], T.S. Brand[a,b], A. Dalle Zotte[c] & M. Cullere[c]

[a] Department of Animal Sciences, University of Stellenbosch, Western Cape, Stellenbosch, 7602, South Africa

[b] Elsenburg Institute for Animal Production, Western Cape, Department of Agriculture, Private Bag XI, Elsenburg 7606, South Africa

[c] Department of Animal Medicine, Production and Health, University of Padova, Agripolis, Viale dell'Università, 16, 35020 Legnaro (PD), Italy

*Corresponding author

Email address: lch@sun.ac.za

Tel: +27 21 808 4747

Fax: +27 21 808 4750

ABSTRACT

The effect of olive oil inclusion on the chemical and sensory characteristics in cabanossi made with ostrich and warthog meat was investigated. Ostrich meat from two cottonseed oilcake (CSOC) dietary inclusion levels (0% CSOC and 9% CSOC), and olive oil were included at three levels (0%, 1% and 2%) resulting in six treatments. The fat content in the cabanossi increased with increasing levels of oil inclusion but were all <10%, which allows it to be classified as a low fat meat product. Total monounsaturated fatty acids in the cabanossi increased whilst total saturated fatty acids and total polyunsaturated fatty acids decreased as olive oil increased. The 0% CSOC cabanossi had a lower fat and higher crude protein content. The inclusion of olive oil at 2% resulted in a cabanossi with increased tenderness, juiciness and cured red meat colour, all factors that appeal to the consumer, while the overall flavour descriptors were not adversely affected by the inclusion of olive oil.

Keywords: Processed meat product; olive oil; ostrich; warthog; chemical; fatty acid; sensory

INTRODUCTION

Over the last decade consumer preferences have changed drastically with an emphasis on nutrition and health, specifically with regards to saturated fat and cholesterol content of meat products (Resurreccion, 2004). In most developed countries obesity and cardiovascular disease has become a topic of grave concern (Williams, 2000) and it has been proposed that intake of total fat and saturated fatty acids (SFA) should decrease to less than 10% of dietary energy (World Health Organisation, 2003). This resulted in the promotion of consuming or changing the diet composition to increased polyunsaturated fatty acids (PUFA) content, specifically the long chain omega-3 PUFA eicosapentaenoic acid (C20:5n-3; EPA) and docosahexaenoic acid (C22:6n-3; DHA) for their beneficial physiological responses. The presence of these PUFA in the typical western diet is very low due to the small amount of fish and fish oils consumed. Williams (2000) explained that even if it is possible to achieve favourable levels of these n-3 PUFA by consuming fish and fish oils, the general consumer perceive these types of products as unpalatable.

With regards to processed meat products however, the interest is not so much in increasing PUFA but with increasing the monounsaturated fatty acids (MUFA) content as it has also been associated with decreasing coronary heart disease (Bloukas & Paneras, 1993), as well as having a protective effect against low density lipoproteins (LDL) oxidation and against oxidative stress in humans (Bolger, Bruton, Lyng & Monahan, 2017). The other objective for focusing on increasing MUFA in processed meat products is because it is not as susceptible to oxidation as PUFA, which could lead to unfavourable sensory properties. A strategy to enhance the nutritional value of meat products by increasing MUFA content and adding natural antioxidants such as tocopherols, as well as reducing cholesterol intake is to replace animal fat with certain vegetable oils (Rodríguez-Carpena, Morcuende & Estévez, 2012).

Pork fat and specifically back fat is generally used as an ingredient in processed meat products and has a high content of SFA and cholesterol (Muguerza Ansorena, Bloukas, & Astiasarán, 2003). A variety of value added meat products have already been manufactured with olive oil as a replacement or partial replacement for animal fat, which has proven to be very successful with regards to nutritional value as well as sensory quality (Bloukas & Paneras, 1993; Pappa, Bloukas & Arvanitoyannis, 2000; Ansorena & Astiasarán, 2004; Rodríguez-Carpena et al., 2012). Rodríguez -Carpena et al. (2012) used avocado, sunflower and olive oil as a replacement for pork backfat in the production of hamburger patties and found the most favourable vegetable oils were avocado and olive oil. Olive oil has positive effects with regards to nutritional value and oxidative stability as well as demonstrating protection against several cancer types (Escrich, Moral, Grau, Costa, & Solanas 2007). It is one of the most monounsaturated vegetable oils containing 56.3 to 86.5% MUFA, 8 to 25% SFA and 3.6 to 21.5% PUFA (Bloukas & Paneras, 1993).

Among exotic meats, ostrich and warthog meat is classified as a healthy source of protein due to its leanness and desirable fatty acid profile (Sales, 1998; Swanepoel, Leslie, & Hoffman, 2016a, Swanepoel, Leslie, Van der Rijst, & Hoffman, 2016b). Another characteristic of ostrich meat is its high ultimate pH (pH_u) which is favourable in processed meat products as it increases the water holding capacity (WHC) (Fisher, Hoffman, & Mellett, 2000) but comes as a disadvantage in terms of shelf life, flavour and its ability to absorb curing agents (Sales & Mellet, 1996). Several value-added ostrich products have already been manufactured but these are mainly based on established technologies and are generally just applied as is to ostrich meat (Fisher et al., 2000). Warthog meat on the other hand has an improved (lower) pH_u ranging around 5.43–5.66, and has successfully been used to produce processed meat products such as back bacon (Swanepoel, 2015) and cabanossi (Swanepoel, et al., 2016a).

Cabanossi, which originated in Poland, is a semi-dry, cured sausage that is smoked and slightly spiced. Generally it consists of pork meat and pork fat (also known as speck in South Africa) but can be produced using a variety of meats such as duck, turkey, and venison and beef and/or sheep fat. This study investigated the use of olive oil as a replacement for pork fat in cabanossi made with ostrich and warthog meat and its effect on the chemical and sensory profile of the cabanossi.

MATERIALS AND METHODS

Processing

The ostrich meat was obtained from the fan fillet of 54 growing ostriches reared on an experimental diet with two levels of cottonseed oilcake (CSOC) meal inclusion (Dalle Zotte, Brand, Hoffman, Schoon, Cullere, & Swart, 2013). The treatment groups were then subdivided into three replicate pens containing nine birds each (approx. 200 m^2/bird). One group received a soy bean oilcake meal based diet with zero CSOC meal (0% CSOC), the other one received a 9% CSOC inclusion diet, replacing the soy bean oilcake meal.

Slaughtering of ostriches took place at commercial abattoir in Swellendam, South Africa. After electrical head stunning (90-110 V, 400-600 mA, 4-6 s), the ostriches were suspended by both legs and exsanguinated by a neck cut to the aortic vein followed by a thoracic stick. Bleeding was followed by plucking, skinning, evisceration and a health inspection. Carcasses were chilled for 24 hours at 0-4 ºC after which the fan fillet (*Iliofibularis* muscle) was excised, vacuum packed and frozen at -20 ºC at Stellenbosch University.

A total number of 58 warthogs were shot using single shot bolt action rifles near Kimberley, South Africa (Swanepoel, et al., 2016b). The animals were exsanguinated by thoracic sticking immediately after shooting, transported to a slaughter facility, weighed and dressed. All the muscles *Longissimus lumborum* (LL) (T_{12}/T_{13} to L_5), *Biceps femoris, Semimembranosus, Semitendinosus, Infraspinatus* and *Supraspinatus* were used for the cabanossi. The muscles obtained were vacuum packed, frozen at -4 ºC, transported to Stellenbosch University and stored at -20 ºC.

Six cabanossi treatments (two ostrich dietary treatments [0% CSOC and 9% CSOC] x three inclusion levels of olive oil [0%, 1% and 2%]) were under investigation: 0% CSOC 0% olive oil (0CSOC0), 0% CSOC 1% olive oil (0CSOC1), 0% CSOC 2% olive oil (0CSOC2), 9% CSOC 0% olive oil (9CSOC0), 9% CSOC 1% olive oil (9CSOC1) and 9% CSOC 2% olive oil (9CSOC2). A single batch of cold-pressed extra-virgin olive oil (Frantoio cultivar) from Tokara Olive Farm (Stellenbosch, South Africa) was used. All the remaining ingredients were provided by Deli Spices (25 Bertie Avenue, Epping 2, Cape Town, South Africa). From the 0% CSOC group, 30 fan fillets were used, and for the 9% CSOC treatment group, 31 fan fillets were used. Each experimental treatment consisted of six independently compiled batches.

The cabanossi recipe for each batch contained 50% of ostrich meat and 50% of warthog meat with one cabanossi spice pack from Deli spice (Bertie Avenue, Epping 2, Cape Town, South Africa). For the 1% olive oil inclusion, 50 ml was added to a 5 kg batch and for the 2% olive oil, 100 ml was added to a 5 kg batch.

The ostrich and warthog meat was defrosted at 4 ºC for 12 hours before being minced through a 12 mm diameter disc and mixed together. The cabanossi spice was then added and mixed by hand. The meat and spice mixture was then minced through a 5 mm diameter disc to ensure adequate mixing of the ingredients. Finally the olive oil was added to the mixture. The cabanossi mixture was placed in a hand sausage filler (Tulsa model, DMD Foodtec Code T-0102 5-89) and filled into natural sheep casings (18–22 mm).

The cabanossi were placed into a Reich Airmaster® UKF SmartSmoker 2000 BE (Reich Klima-Räuchertechnik, Urbach, Germany) with a TradiSmoker LS 500 HP electronic that was controlled automatically by a Microprocessor (Unicontrol 2000). The program settings is depicted in Table 1. The cabanossi were removed after processing, and from each cabanossi batch, six short sausages were selected and analysed further.

Proximate analysis

Cabanossi samples of the six treatments (of a randomly selected cabanossi within each batch) were homogenised and analysed for total percentage of moisture, ash, fat and crude protein content.

Proximate analysis of the cabanossi samples were analysed according to the Association of Official Analytical Chemist's Standard Techniques (AOAC). A 2.5 g homogenized cabanossi sample was placed in a drying oven at 100 – 105 ºC for 24 hours (AOAC Official method 934.01) (AOAC, 2000a) in order to determine the moisture content after which the same samples was used to determine ash content by incinerating in an oven at 500 ºC for 6 hours (AOAC 942.05) (AOAC, 2000b). The chloroform/methanol (1:2 v/v) extraction method stipulated by Lee, Trevino, & Chaiyawat (1996) was used to determine the total lipid (%) of a 5 g homogenised cabanossi sample. The fat free sample was placed in a drying oven to retain a moisture free sample. The % nitrogen (N) was then determined on the fat and moisture free sample based on the Dumas combustion method 992.15 (AOAC, 2000c) using a Leco Nitrogen/Protein Analyser (FP-528, Leco Corporation). The Leco was calibrated with EDTA samples (Leco corporation, 3000 Lakeview Avenue, St. Joseph, MI 49085-2396, USA, Part no. 502-092, Lot no. 1055) prior to every analyses session. The results were presented in % N which was then multiplied by a conversion factor (6.25) in order to determine the crude protein content of the cabanossi samples. All proximate analyses are controlled by a National inter-laboratory scheme (AgriLASA: Agricultural Laboratory Association of South Africa). In order to assess the accuracy of the analyses, blind samples are analysed every other month.

Fatty acid analysis

A 2 g cabanossi sample was extracted with a chloroform:methanol (1:2 v/v) solution according to a modified method of Folch, Lees, and Sloane-Stanley (1957). All the extraction solvents contained 0.01% butylated hydroxytoluene (BHT) as an antioxidant. A polytron mixer (WiggenHauser, D-500 Homogenizer) was used to homogenise the sample with the extraction solvent. Heptadecanoic acid (C17:0) was used as an internal standard (catalogue number H3500, Sigma–Aldrich Inc., 3050 Spruce Street, St. Louis, MO 63103, USA) to quantify the individual fatty acids. A sub-sample of the extracted lipids was transmethylated for 2 h at 70 °C using a methanol/sulphuric acid (19:1 v/v) solution as transmethylating agent. After cooling to room temperature, the resulting fatty acid methyl esters (FAMEs) were extracted with water and hexane. The top hexane phase was transferred to a spotting tube and dried under nitrogen. Analysis was done on a Thermo Focus GC equipped with a flame ionized detector using a BPX70 capillary column (60 m x 0.25 mm internal diameter, SGE, Australia). Gas flow rates were 25 ml/min for hydrogen and 2-4 ml/min for the hydrogen carrier gas. Temperature programming was linear at 3.4 °C/min, with an initial temperature of 60 °C, a final temperature of 160 °C, an injector temperature of 220 °C and a detector temperature of 260 °C. The FAMEs were identified by comparing the retention times to those of a standard FAME mixture (SupelcoTM 37 Component FAME Mix, 10 mg/ml in CH_2Cl_2, Catalogue Number 47885-U. Supelco, North Harrison Road, Bellefonte, PA 16823-0048, USA).

Descriptive sensory analysis

A descriptive sensory analysis was performed on all six cabanossi treatments. The panel was chosen based on their experience in sensory analysis and on their availability. Panellists were trained, in accordance with the generic descriptive analysis techniques, as described by Lawless and Heymann (2010). A panel of ten members were trained in two interactive sessions to familiarise the panellists with the treatments and to identify the sensory characteristics to be evaluated. A questionnaire was compiled during the first training session. The questionnaire was refined and tested during the second training session. An unstructured line scale ranging from zero (low intensity) on the left side and 100 (high intensity) on the right side was used to analyse the sensory characteristics, according to the guidelines of the American Meat Science Association (AMSA) (American Meat Science Association, 1995). Table 3 depicts the characteristics and definitions used. The sensory tests were performed in individual booths in a temperature (21 °C) and light controlled (equivalent to daylight) room. Two samples (2 cm in length) of each of the six treatments were served to the panellists in a randomised order in six sessions, in order to evaluate all the replicates. Distilled water, apple and water crackers were given to the panellists with each sensory session. Each sample was coded with randomly selected three digit numbers.

Statistical analysis

The experimental design was a randomised block with each of the six treatment combinations randomly replicated in six batches. The treatment design was a 2x3 factorial with two feeding treatments (0CSOC, 9CSOC) and three levels of olive oil (0%, 1%, 2%).

The model for the experimental design for the proximate and fatty acid data is defined by the following equation:

$$\text{Model: } y_{ijk} = \mu + t_i + o_j + to_{ij} + \varepsilon_{ijk}$$

Where y_{ijk} defines the response obtained for the k'th observation in the i'th level of the feeding treatment and the j'th level of the olive oil treatment. The overall mean is defined by μ, the effect due to feeding treatment *i* is presented by t_i, o_j presents the effect due to olive oil level j. The effect due to the i'th level of the feeding treatment and the j'th level of the olive oil treatment is defined by to_{ij} and ε_{ij} defines the random error associated with response on the k'th observation in the i'th level of the feeding treatment and the j'th level of the olive oil treatment.

The model for the experimental design for the sensory data is defined by the following equation:

$$\text{Model: } y_{ijk} = \mu + s_k + t_i + o_j + to_{ij} + \varepsilon_{ijk}$$

Where y_{ijk} presents the response obtained for the i'th level of the feeding treatment and the j'th level of the olive oil treatment in the k'th evaluation session, μ depicts the overall mean, the effect due to evaluation session k is presented by s_k. The effect due to feeding treatment i is defined by t_i, where o_j presents the effect due to olive oil level j. The effect due to the i'th level of the feeding treatment and the j'th level of the olive oil treatment is depicted by to_{ij} and εij depicts the random error associated with response on the i'th level of the feeding treatment and the j'th level of the olive oil treatment in the k'th evaluation session.

Univariate analysis of variance was performed, according to the model for the experimental design, on all sensory and chemical variables accessed using the GLM (General Linear Models) Procedure of SAS (Version 9.2; SAS Institute Inc, Cary, USA). Sensory data was pre-processed by subjecting it to a test-retest analysis of variance (ANOVA), using SAS, to test for panel reliability. Judge*Replication and Judge*Sample interactions were used respectively as measures of temporal stability (precision) and internal consistency (homogeneity) of the panel. Shapiro-Wilk test was performed to test for normality (Shapiro, 1965). Student’s t-least significant difference was calculated at the 5% level to compare treatment means (Ott, 1998). A probability level of 5% was considered significant for all significance tests.

In addition to the univariate ANOVAs, the data was also subjected to Multivariate methods such as principal component analysis (PCA) and discriminate analysis (DA) (XLStat, Version 2011, Addinsoft, New York, USA) to visualise and elucidate the relationships between the samples and their attributes.

RESULTS AND DISCUSSION

Proximate analysis

The proximate composition of the cabanossi is presented in Table 5. No significant differences were found for the moisture content between treatments. This was expected as all batches were prepared according to the same recipe and process and had a similar weight loss percentage of approximately 40%. Although the moisture loss was much higher than for typical semi dried sausages (15–20%), it is close to the typical ± 45% weight loss suggested for cabanossi (Swanepoel, et al., 2016a) .

Crude protein was highest ($P \leq 0.05$) in the 0 and 1% olive oil inclusion in the 0% CSOC (0CSOC) group and lowest in the 9% CSOC (9CSOC) group with 2% olive oil (Table 5), and fat percentage was higher ($P \leq 0.05$) for the 9CSOC group with 2% olive oil inclusion than the 0% and 1% olive oil treatments in the 0CSOC group. No major differences were expected as the ostrich meat (0CS0C and 9CSOC) used in the production of the cabanossi (Table 2) did not differ ($P > 0.05$) in proximate composition. Differences observed are therefore mainly contributed to the olive oil inclusion at 1% and 2%. Warthog meat used in this study presented a slightly higher fat content than the 0CSOC and 9CSOC ostrich meat and was higher than that determined by Swanepoel et al. (2016a) of ≤ 2.2%, but this was because subcutaneous and belly fat was included in the raw material used.

Semi-dry and dry sausages generally contain quite high levels of fat, as much as 40% in the final product (Ansorena & Astiasarán, 2004). Typically cabanossi contains 20% in the raw batch which increases to approximately 40% with a weight loss of 45% in the dried product. The cabanossi produced here can be considered a low fat version with a fat content of less than 10%, with a much higher crude protein content (Table 5). Furthermore, the 0CSOC0 and 0CSOC1 cabanossi is comparable to the warthog and pork fat cabanossi produced by Swanepoel et al. (2016a) in terms of low fat content (6.9%), while all treatments were lower in fat than the pork and pork fat cabanossi (13.7%) they had produced as control.

Fatty acid analysis

Table 6 presents the fatty acid (FA) composition of the cabanossi and Figure 1 shows the difference in the fatty acid profiles by means of the Discriminant Analysis (DA).

From the DA plot the differences in fatty acid profile between 0CSOC0 and 0CSOC1 and 0CSOC2 is visible as the centroid for 0CS0C0 is in an outlier position. Furthermore, 9CSOC0 is also removed from 9CSOC1 and 9CSOC2 indicating the difference in FA profile between these treatments. The grouping of 9CSOC1, 9CSOC2 and 0CSOC2 indicates a close resemblance in FA profile as is the grouping of 9CSOC0 and 0CSOC1.

The FA most prevalent in olive oil is oleic acid (C18:1n-9). As expected, the concentration of oleic acid increased proportionally to the amount of olive oil added, whereas the proportion of the most prevalent saturated (palmitic; C16:0) and polyunsaturated (linoleic; C18:2n-6) FA decreased accordingly for both treatments. While olive oil does contain varying levels of linoleic acid, the olive oil used in this study possibly contained levels below the detection range of the technique used. Nevertheless, the exotic meats used also contained varying levels of linoleic acid and the increase of olive oil could therefore have a diluting effect on the oleic acid present in the cabanossi.

No significant differences were found for the ratio between polyunsaturated fatty acids and saturated fatty acids (PUFA:SFA). In terms of human health, the balance between PUFA and SFA, and the content of n-3 PUFA in human diets are very important for their role in positive health benefits (Williams, 2000). The World Health Organization (2003) recommends an increased consumption of PUFA and decreased consumption of SFA, a sufficient intake of essential FA (linoleic, α-linolenic [C18.3n-3]) and eicosapentaenoic (C20.5n-3; EPA) and docosahexaenoic (C22:6n-3; DHA) acid (daily intake of 2 g EPA and DHA combined). The cabanossi produced here may provide varying levels of these PUFA although the exact amounts (mg/g) remain unknown.

Sensory attributes

Although olive oil inclusion may result in a meat product with a lower total fat and SFA contents, it may alter the processing parameters and physiochemical and sensory profile, depending on the level of fat replaced with plant oils in processed meat products (Bloukas Paneras, & Fournitzis, 1997; Muguerza, Gimeno, Ansorena, Bloukas, & Astiasarán, 2001). For processed meat products the visual appearance followed by flavour and texture, which can vary considerably between products, determines the general likeability and intent to purchase of processed meat products (Resurreccion, 2004). Smoky aroma was scored significantly higher for the 0CSOC and 9CSOC with 0% olive oil and lowest for the 9CSOC with 2% olive oil (Table 7). The higher amount of fat and olive oil in these treatments probably resulted in a moister (oilier) surface of the semi-dried sausage during processing which discouraged smoke adhesion, as it is general knowledge that products with a drier surface allows increased adherence of smoke particles. Furthermore, unsaturated fats/oils have a lower melting point which could also lead to a moister surface area. However, although there were differences in the smoky flavour, these can be considered slight overall indicating that the smoky flavour was obtained despite the lower surface adhesion. The olive oil and fatty aroma followed the opposite but expected trend i.e. increasing with increasing levels of olive oil.

Total fat content and inclusion of olive oil affects the visual appearance of meat and meat products, which is further influenced by production parameters and time during processing and storage (Bloukas et al., 1997; Muguerza et al., 2001; Muguerza, Fista, Ansorena, Astiasarán, & Bloukas 2002; Kayaard, & Gök, 2003). In our study, the visible fat content of the cabanossi did not differ among treatments, which may be expected as no animal fat were present, while the oily appearance did differ which can also be expected. The cured meat colour also differed, with 9CSOC with 2% olive oil having the most intense red cured meat colour in comparison to the 0CSOC with 0% and 1% olive oil (Table 7). The addition of plant oils to meat products can have significant effects on the colour and appearance, as plant oils contain various colour pigments and may increase the colour saturation of the product (Rodríguez-Carpena et al., 2012). Olive oil may contain pigments that vary from bluish-green (chlorophyll a) to red-orange (β-carotene) (Moyano, Heredia, & Meléndez-Martínez, 2010). However, in the present investigation the same olive oil source was used and it is therefore questionable whether the olive oil was responsible for the cabanossi appearing more intense red; this aspect warrants further research. Rodríguez-Carpena et al. (2012) suggested that consumers might not appreciate colour changes although Kayaard and Gök (2003) found that differences in appearance of soudjouk made with different levels of olive oil did not affect consumers' general acceptability.

There were no differences in the cured pork or peppery flavour, which was expected as the product was made according to the same recipe and process, whereas an increase in moisture and fat dilutes the perception of saltiness (Pappa et al., 2000). With regards to texture, the lower fat content of the 0CSOC with 0% olive oil was likely responsible for the firmer texture of this cabanossi treatment, as the inclusion of more unsaturated fats is expected to produce a product with a less firm (softer) texture (Bloukas et al., 1997). Juiciness and tenderness were both significantly higher in the 0CSOC and 9CSOC with 2% olive oil, as expected from the higher fat content. According to Hoffman, Muller, Cloete and

Brand (2008), sensory tenderness is correlated to the amount of moisture or juiciness the panellist perceives during the first initial bites of the meat sample.

Relationship between attributes and chemical composition

A principal component analysis (PCA) bi-plot of the sensory, proximate and significant FA is displayed in Figure 2(a). The combination of the two components; Factor (F) 1 and F2 explained 48.42% of the total variance of which F1 explained 36.99% of the total variance and F2 explained 11.43% of the total variance. In Figure 2(b), the discriminant analysis (DA) presents the differences between the six treatments for sensory attributes, proximate composition and FA profile. The combination of the two components of the DA, F1 and F2 explained 100.0% of the total variance of which F1 explained 95.69% of the total variance and F2 explained 4.31% of the total variance. The treatments presented on the DA plot (Figure 1(b)) does not present such a clear indication of how the treatments differed, as they are all situated in the middle of the plot with no centroids presented as outliers. The treatments with 1% and 2% olive oil inclusion does however lie on the opposite side of F1 from the 0% olive oil treatments, indicating a significant difference as F1 explained 95.69% of the total variance.

As explained, 9CSOC2 presented significantly higher scores for tenderness, juiciness, olive oil aroma and flavour as well as cured red meat colour and oily appearance which are reiterated by the PCA bi-plot (Figure 2a). A strong correlation between olive oil flavour and olive oil aroma is visible. This further substantiates the results presented in Table 7, where the 0CSOC with 0% olive oil had the lowest olive oil aroma as well as olive oil flavour. Percentage fat correlated negatively with saltiness and positively with olive oil aroma, tenderness and juiciness. All of these strong correlations support the results with regards to the effect of fat content on saltiness, juiciness and tenderness. Fatty meat aroma and oily appearance presents a strong correlation. The association of 9CSOC2 treatment with these attributes was further supported by the significantly higher mean scores for fatty meat aroma and surface appearance. The drying and smoking process caused the olive oil to move towards the surface of the sausage creating this oily appearance on the surface which enhanced the fatty meat and olive oil aroma.

A visible indication of the effect of oleic acid being the main FA responsible for the total MUFA content in the ostrich cabanossi produced with olive oil is presented in the PCA bi-plot. This specific FA increased as olive oil inclusion increased (Table 6). As expected, SFA and PUFA are situated on opposite sides to the treatments containing olive oil as the concentrations of total SFA and PUFA decreased slightly as olive oil % increased.

CONCLUSION

The use of olive oil as a replacement for pork fat at an inclusion level of 1% and 2% in the production of the exotic cabanossi resulted in a value added, low fat meat product that satisfies the need of the modern-day health conscious consumer. The olive oil resulted in an increase of percentage fat (in the form of oil) within the product but all treatments were still classified as a low-fat meat product. The addition of olive oil resulted in cabanossi with increasing levels of MUFA and decreasing amounts of PUFA and SFA as olive oil inclusion increased. From a technical perspective, an increase in MUFA rather than PUFA is beneficial with regards to risks of rancidity due to lipid oxidation, as the longer chain PUFA are especially more susceptible to oxidation which reduces the shelf life of a meat product. The inclusion of olive oil at 2% resulted in cabanossi with increased tenderness and juiciness, two factors deemed as most important from a consumer's perspective. As expected, the use of olive oil overshadowed any differences that may have been present due to the use of different levels of cotton seed oil cake in the diets of the ostriches. A processed meat product where olive oil replaces pork fat therefore seems to be a viable option to increase the variety of value added meat products available to the modern consumer.

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REFERENCES

American Meat Science Association (AMSA). (1995). Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat. Chicago, USA: National Livestock and Meat Board.

Ansorena, D., & Astiasarán, I. (2004). Effect of storage and packaging on fatty acid composition and oxidation in dry fermented sausages made with added olive oil and antioxidants. *Meat Science,* 67, 237-244.

AOAC International. (2002a). Official methods of analysis. Arlington, Virginia, USA: Association of Official Analytical Chemists Inc. Loss on drying (moisture) at 95–100°C for feeds. (17^{th} ed.) AOAC Official Method 934.01.

AOAC International. (2002b). Official methods of analysis. Arlington, Virginia, USA: Association of Official Analytical Chemists Inc. (17^{th} ed.). Ash of Animal Feed. AOAC Official Method 942.05.

AOAC International. (2002c). Official methods of analysis, Arlington, Virginia, USA: Association of Official Analytical Chemists Inc. (17^{th} ed.). Dumas Combustion method. AOAC Official Method 992.15.

Bolger, N., Bruton, N.P., Lyng, J.G., & Monahan, F.J. (2017). Comminuted meat products - consumption, composition, and approaches to healthier formulations. *Food Reviews International*, *33*, 143-147.

Bloukas, J., & Paneras, E. (1993). Substituting olive oil for pork backfat affects quality of low-fat frankfurters. *Journal of Food Science, 58*, 705-709.

Bloukas, J., Paneras, E., & Fournitzis, G. (1997). Effect of replacing pork backfat with olive oil on processing and quality characteristics of fermented sausages. *Meat Science, 45*, 133-144.

Dalle Zotte, A., Brand, T.S., Hoffman, L.C., Schoon, K., Cullere, M., & Swart, R. (2013). Effect of cottonseed oilcake inclusion on ostrich growth performance and meat chemical composition. Meat Science, 93, 194–200.

Escrich, E., Moral, R., Grau, L., Costa, I., & Solanas, M. (2007). Molecular mechanisms of the effects of olive oil and other dietary lipids on cancer. *Molecular Nutrition & Food Research, 51*, 1279-1292.

Fisher, P., Hoffman, L. C., & Mellett, F. D. (2000). Processing and nutritional characteristics of value added ostrich products. *Meat Science, 55*, 251-254.

Folch, J., Lees, M., & Sloane-Stanley, G. (1957). A simple method for the isolation and purification of total lipids from animal tissues. *Journal of Biological Chemistry, 226*, 497-509.

Hoffman, L. C., Muller, M., Cloete, S. W. P., & Brand, M. (2008). Physical and sensory meat quality of South African Black ostriches (*Struthio camelus* var. *domesticus*), Zimbabwean Blue ostriches (*Struthio camelus australis*) and their hybrid. *Meat Science, 79*, 365-374.

Kayaard, S., & Gök, V. (2004). Effect of replacing beef fat with olive oil on quality characteristics of Turkish soudjouk (sucuk). *Meat Science, 66*, 249-257.

Lawless, H. T., & Heymann, H. (2010). *Sensory evaluation of food: Principals and practises* (2nd ed.). New York, USA: Chapman & Hall.

Lawrie, R. A., & Ledward, D. A. (2006). *Lawrie's meat science* (7th ed.). Cambridge, England: Woodhead Publishing.

Lee, C., Trevino, B. & Chaiyawat, M. (1996). A simple and rapid solvent extraction method for determining total lipids in fish tissue. *Journal of AOAC International*, 79, 487-492.

Moyano, M. J., Heredia, F. J., & Meléndez-Martínez, A. J. (2010). The color of olive oils: The pigments and their likely health benefits and visual and instrumental methods of analysis the color of olive oils: The pigments and their likely health benefits and visual and instrumental methods of. *Comprehensive Reviews in Food Science and Food Safety*, *9*, 278–291.

Muguerza, E., Gimeno, O., Ansorena, D., Bloukas, J., & Astiasarán, I. (2001). Effect of replacing pork backfat with pre-emulsified olive oil on lipid fraction and sensory quality of chorizo de Pamplona - a traditional Spanish fermented sausage. *Meat Science, 59*, 251-258.

Muguerza, E., Fista, G., Ansorena, D., Astiasarán, I., & Bloukas, J. (2002). Effect of fat level and partial replacement of pork backfat with olive oil on processing and quality characteristics of fermented sausages. *Meat Science, 61*, 397-404.

Muguerza, E., Ansorena, D., Bloukas, J., & Astiasarán, I. (2003). Effect of fat level and partial replacement of pork backfat with olive oil on the lipid oxidation and volatile compounds of Greek dry fermented sausages. *Journal of Food Science, 68*, 1531-1536.

Ott, R. L. (1998). *An introduction to statistical methods and data analysis*. Belmont, California:Duxbury Press.

Pappa, I., Bloukas, J., & Arvanitoyannis, I. (2000). Optimization of salt, olive oil and pectin level for low-fat frankfurters produced by replacing pork backfat with olive oil. *Meat Science, 56*, 81-88.

Resurreccion, A. (2004). Sensory aspects of consumer choices for meat and meat products. *Meat Science, 66*, 11-20.

Rodríguez-Carpena, J., Morcuende, D., & Estévez, M. (2012). Avocado, sunflower and olive oils as replacers of pork back-fat in burger patties: Effect on lipid composition, oxidative stability and quality traits. *Meat Science, 90, 106-115.*

Sales, J. (1998). Fatty acid composition and cholesterol content of different ostrich muscles. *Meat Science, 49*, 489-492.

Sales, J., & Mellett, F. (1996). Post-mortem pH decline in different ostrich muscles. *Meat Science, 42*, 235-238.

Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). *Biometrika, 52*, 591-611.

Swanepoel, M. (2015). Distribution, management and utilisation of the extra-limital common warthog (*Phacochoerus africanus*) in parts of the Northern Cape and Free State provinces, South Africa. PhD dissertation, University of Stellenbosch.

Swanepoel, M., Leslie, A. J., & Hoffman, L. C. (2016a). Comparative analyses of the chemical and sensory parameters and consumer preference of a semi-dried smoked meat product (cabanossi) produced with warthog (*Phacochoerus africanus*) and domestic pork meat. *Meat Science, 114*, 103–113.

Swanepoel, M., Leslie, A. J., Van der Rijst, & Hoffman, L. C. (2016b). Physical and chemical characteristics of warthog (*Phacochoerus africanus*) meat as influenced by sex. *Meat Science, 46*, 103–120.

Williams, C. M. (2000). Dietary fatty acids and human health. *Annales De Zootechnie, 49,* 165-180.

World Health Organization (2003). Diet, Nutrition and the Prevention of Chronic Diseases. Report of a Joint WHO/FAO Expert Consultation. WHO Technical Report Series no. 916. http://www.who.int/dietphysicalactivity/publications/trs916/en/ (accessed 02/02/2018).

Table 1: Production program for the cabanossi made in a Reich Airmaster® UKF SmartSmoker 2000 BE.

Activity	Temperature (ºC)	Relative Humidity (%)	Time (hrs)
Reddening	40	80	2.00
Drying	30	30	2.00
Cold smoking	30	20	0.30
Smoke destruction	30	30	0.10
Drying	30	30	2.00
Cold smoking	30	20	0.20
Smoke destruction	30	20	0.10
Drying	30	30	8.00

Table 2: Means (± standard deviation) of proximate composition (%) of the raw materials used in production of the cabanossi: warthog meat, ostrich meat from ostrich fed standard diet with no cottonseed oilcake (CSOC) meal (Control [Ctr]), and ostrich meat from ostrich fed 9% cottonseed oilcake meal.

Meat	**Warthog**	**Ostrich ()% CSOC)**	**Ostrich (9% CSOC)**
Moisture	70.6	75.6 ± 0.83	76.1 ± 1.31
Crude Protein	22.0	20.4 ± 0.61	19.5 ± 1.75
Fat	5.8	3.8 ± 0.37	4.6 ± 0.67
Ash	1.2	1.1 ± 0.03	1.1 ± 0.04

Table 3: Fatty acid profile (% of total FAME) of the raw materials used in production of the cabanossi.

	Olive oil	Warthog meat	Ostrich meat [(1)] (0% CSOC	Ostrich meat [(1)] (9% CSOC
Saturated fatty acids (SFA)				
C14:0	0.0	1.2	0.4 ± 0.16	0.6 ± 0.24
C15:0	0.0	0.3	0.2 ± 0.04	0.2 ± 0.04
C16:0	19.1	33.1	22.3 ± 8.39	27.1 ± 2.06
C18:0	1.1	15.9	13.8 ± 0.77	16.1 ± 2.33
C20:0	0.0	0.4	0.3 ± 0.04	0.3 ± 0.09
C21:0	0.0	0.1	0.1 ± 0.01	0.1 ± 0.12
C22:0	0.0	0.2	0.6 ± 0.08	0.6 ± 0.13
C24:0	0.0	0.0	0.1 ± 0.02	0.1 ± 0.07
Total SFA	20.2	51.2	37.7 ± 8.46	45.1 ± 2.58
Monounsaturated fatty acids (MUFA)				
C14:1	0.0	0.1	0.1 ± 0.02	0.1 ± 0.03
C16:1	0.2	3.6	6.6 ± 1.59	4.3 ± 0.96
C18:1n-9c	78.1	41.4	26.8 ± 8.16	25.2 ± 0.89
C18:1n-9t	0.9	0.1	0.2 ± 0.03	0.5 ± 0.43
C20:1	0.1	0.1	0.1 ± 0.01	0.1 ± 0.02
C22:1n-9	0.0	1.6	0.1 ± 0.02	0.3 ± 0.28
C24:1	0.0	0.1	0.3 ± 0.06	0.3 ± 0.08
Total MUFA	79.35	46.9	33.8 ± 8.63	30.3 ± 1.31
Polyunsaturated fatty acids (PUFA)				
C18:2n-6c	0.0	0.3	17.9 ± 1.47	18.6 ± 1.70
C18:2n-6t	0.1	0.1	0.0 ± 0.01	0.1 ± 0.02
C18:3n-6	0.0	0.0	0.0 ± 0.00	0.0 ± 0.00
C18:3n-3	0.2	0.3	0.3 ± 0.05	0.3 ± 0.03
C20:2	0.1	0.2	0.3 ± 0.04	0.4 ± 0.07
C20:3n-6	0.0	0.0	3.3 ± 0.49	1.0 ± 1.55
C20:3n-3	0.0	0.0	0.1 ± 0.00	0.1 ± 0.06
C20:4n-6	0.0	0.1	0.0 ± 0.00	0.0 ± 0.01

C20:5n-3	0.0	0.0	0.0 ± 0.01	0.0 ± 0.01
C22:2	0.0	0.1	0.1 ± 0.02	0.2 ± 0.32
C22:5n-3	0.0	0.0	0.0 ± 0.00	0.3 ± 0.39
C22:6n-3	0.0	0.1	0.3 ± 0.04	0.3 ± 0.17
Total PUFA	0.4	1.2	22.3 ± 1.32	21.2 ± 1.29
PUFA/SFA	0.02	0.0	0.6 ± 0.20	0.5 ± 0.05
n-6/n-3	2.83	0.7	31.4 ± 4.01	22.1 ± 6.73

(1) Mean ± standard deviation

Table 4: Definition and scale for each attribute used for the descriptive sensory analysis of smoked and dried ostrich cabanossi.

Descriptor	Definition	Scale
Aroma		
Smoky aroma	Aroma associated with smoked meats	0 = Extremely bland 100 = Extremely intense
Olive oil aroma	Aroma associated with olive oil	0 = Extremely bland 100 = Extremely intense
Fatty meat aroma	Aroma associated with meat products containing large amounts of fat	0 = Extremely bland 100 = Extremely intense
Appearance		
Visible fat	Amount of fat visibly present on visual inspection	0 = No fat present 100 = Large amount of fat present
Cured red meat colour	Colour associated with cured meat products	0 = Light red colour 100 = Intense dark red colour
Oily appearance	Presence of oily substance on surface	0 = Dry surface appearance 100 = Extremely oily appearance
Flavour		
Cured pork flavour	Flavour associated with cured pork products	0 = Extremely bland 100 = Extremely intense
Game flavour	Flavour associated with game meat	0 = Extremely bland 100 = Extremely intense
Fishy flavour	Flavour associated with fish products	0 = Extremely bland 100 = Extremely intense
Smoky flavour	Flavour associated with smoked meat products	0 = Extremely bland 100 = Extremely intense
Saltiness	Impression of amount of salt present	0 = Extremely bland 100 = Extremely salty
Peppery flavour	Flavour associated with pepper	0 = Extremely bland 100 = Extremely intense
Olive oil flavour	Flavour associated with olive oil	0 = Extremely bland 100 = Extremely intense
Texture		
Tenderness	Impression of tenderness after first five chews	0 = Extremely tough

	using the molar teeth	100 = Extremely tender
Juiciness	The level of juiciness perceived after the first five chews using the molar teeth	0 = Extremely dry 100 = Extremely juicy
Firmness	The degree of force required to bite the sample	0 = Extremely soft 100 = Extremely firm

Table 5: Means (± standard deviation) of the proximate composition (%) of smoked and dried cabanossi obtained with 2 types of ostrich meat (0% CSOC and 9% CSOC$^{(1)}$) and three levels of olive oil.

	Treatments					
	0% CSOC			**9% CSOC**		
	0%	**1%**	**2%**	**0%**	**1%**	**2%**
Moisture	50.9 ± 2.33	50.5 ± 1.60	50.5 ± 1.66	50.0 ± 1.58	50.0 ± 1.58	50.0 ± 0.72
Crude Protein	$36.2^{a} \pm 2.24$	$36.3^{a} \pm 2.27$	$35.5^{ab} \pm 1.10$	$35.4^{ab} \pm 2.73$	$34.6^{ab} \pm 0.81$	$33.6^{b} \pm 2.03$
Fat	$6.6^{b} \pm 1.96$	$6.5^{b} \pm 1.68$	$7.7^{ab} \pm 1.09$	$7.8^{ab} \pm 2.65$	$8.4^{ab} \pm 2.05$	$9.6^{a} \pm 3.12$
Ash	$5.4^{ab} \pm 0.39$	$6.2^{ab} \pm 1.90$	$5.4^{ab} \pm 0.16$	$5.5^{ab} \pm 1.50$	$5.1^{b} \pm 0.34$	$6.9^{a} \pm 2.22$

$^{a,b\ c}$ Rows with different letters differ significantly ($P \leq 0.05$); $^{(1)}$ CSOC= cottonseed oilcake

Table 6: Means (± standard deviation) of the fatty acids (% of total FAME) of olive oil and of smoked and dried cabanossi obtained with 2 types of ostrich meat (0% CSOC and 9% CSOC[(1)]) and three levels of olive oil.

		Treatments					
Fatty acid[#]	Olive oil	0% CSOC			9% CSOC		
		0%	1%	2%	0%	1%	2%
Saturated Fatty Acids (SFA)							
C16:0	19.1	29.1^{ab} ± 10.12	17.9^{bc} ± 12.36	13.2^{c} ± 8.84	32.5^{a} ± 12.19	20.7^{abc} ± 10.05	18.6^{bc} ± 11.42
C18:0	1.1	8.6^{a} ± 4.79	4.1^{ab} ± 0.94	3.9^{ab} ± 2.16	8.6^{a} ± 7.73	5.8^{ab} ± 3.17	3.4^{b} ± 0.40
Total SFA	20.2	38.9^{ab} ± 11.00	22.4^{c} ± 11.98	17.5^{c} ± 9.50	42.2^{a} ± 17.6	27.1^{bc} ± 10.14	22.3^{c} ± 11.07
Monounsaturated Fatty Acids (MUFA)							
C16:1	0.2	3.0^{a} ± 1.83	1.3^{b} ± 0.34	1.1^{b} ± 0.20	1.3^{b} ± 0.10	1.4^{b} ± 0.76	0.8^{b} ± 0.11
C18:1n-9c	78.1	44.5^{bc} ± 13.69	67.7^{a} ± 10.53	72.8^{a} ± 13.22	43.4^{c} ± 18.86	60.9^{ab} ± 15.09	70.9^{a} ± 11.50
Total MUFA	79.35	48.9^{bc} ± 11.67	69.3^{a} ± 10.86	74.1^{a} ± 13.30	45.1^{c} ± 18.75	62.6^{ab} ± 14.66	71.9^{a} ± 11.62
Poly unsaturated Fatty Acids (PUFA)							
C18:2n-6c	0.0	8.4^{a} ± 5.29	4.1^{ab} ± 1.38	2.7^{b} ± 2.22	5.4^{ab} ± 4.93	4.1^{ab} ± 4.80	2.6^{b} ± 1.46
C18:3n-6	0.2	2.4 ± 2.86	3.5 ± 0.62	4.6 ± 4.86	5.7 ± 4.77	5.3 ± 2.50	2.6 ± 0.69
Total PUFA	0.4	11.6^{a} ± 3.46	7.9^{ab} ± 1.47	7.6^{ab} ± 3.78	11.6^{a} ± 4.18	9.8^{ab} ± 6.02	5.5^{b} ± 1.76
PUFA/SFA	0.02	0.3 ± 0.19	0.5 ± 0.22	0.5 ± 0.16	0.3 ± 0.17	0.4 ± 0.17	0.3 ± 0.20
n-6/n-3	2.83	29.7 ± 16.49	36.7 ± 14.49	33.3 ± 26.74	39.7 ± 18.31	31.2 ± 11.24	28.4 ± 12.86

$^{a,b\ c}$Rows with different letters differ significantly (P≤0.05); * only specific FA > 1.0% depicted in table. [(1)] CSOC= cottonseed oilcake

Table 7: Means (± Standard deviation) of the sensory attributes of smoked and dried ostrich cabanossi obtained with 2 types of ostrich meat (0% CSOC and 9% CSOC$^{(1)}$) and three levels of olive oil.

Attributes	**Treatments**					
	0% CSOC			**9% CSOC**		
	0%	**1%**	**2%**	**0%**	**1%**	**2%**
Aroma						
Smoky aroma	68.1^{a} ± 5.14	67.2^{ab} ± 5.18	67.4^{ab} ± 5.24	68.1^{a} ± 4.72	67.2^{ab} ± 5.12	66.3^{b} ± 6.08
Olive oil aroma	2.9^{c} ± 4.35	4.2^{b} ± 4.94	4.1^{b} ± 4.62	3.9^{bc} ± 4.56	4.0^{b} ± 5.00	5.3^{a} ± 5.19
Fatty meat aroma	11.5^{c} ± 7.89	12.6^{bc} ± 7.03	13.5^{ab} ± 8.24	11.7^{bc} ± 7.70	11.2^{c} ± 7.16	14.8^{a} ± 7.07
Appearance						
Visible fat	8.8 ± 8.18	8.9 ± 5.05	10.1 ± 6.71	10.1 ± 6.56	9.1 ± 7.00	10.6 ± 5.61
Cured red meat colour	70.8^{b} ± 8.21	70.9^{b} ± 7.94	72.7^{ab} ± 6.67	71.4^{ab} ± 8.36	71.4^{ab} ± 8.68	73.4^{a} ± 6.54
Oily appearance	36.5^{c} ± 9.58	41.4^{b} ± 10.89	45.2^{a} ± 8.82	38.5^{bc} ± 10.54	40.8^{b} ± 10.37	46.3^{a} ± 10.06
Flavour						
Cured pork flavour	72.7 ± 6.98	72.7 ± 6.42	73.3 ± 6.54	73.9 ± 6.57	73.6 ± 6.42	72.7 ± 7.29
Game flavour	0	0	0	0.0 ± 0.39	0	0
Fishy flavour	1.1 ± 3.74	0.9 ± 2.45	1.1 ± 2.92	0.9 ± 2.69	1.3 ± 3.08	1.2 ± 2.89
Smoky flavour	58.9^{a} ± 6.33	58.8^{ab} ± 6.44	57.4^{ab} ± 6.55	57.3^{b} ± 6.26	57.8^{ab} ± 5.8	57.9^{ab} ± 6.48
Saltiness	28.9^{a} ± 4.78	28.9^{a} ± 3.09	28.5^{ab} ± 5.44	27.8^{b} ± 5.04	27.7^{b} ± 5.20	28.1^{ab} ± 5.24
Peppery flavour	56.9 ± 16.08	57.6 ± 13.21	56.2 ± 14.82	55.9 ± 15.78	56.9 ± 15.81	56. 1 ± 16.09
Olive oil flavour	6.1^{c} ± 8.17	7.3^{bc} ± 7.91	10.2^{a} ± 8.54	7.2^{c} ± 8.86	7.9^{b} ± 8.59	10.5^{a} ± 8.10
Texture						
Tenderness	71.3^{b} ± 7.37	72.9^{ab} ± 7.52	75.2^{a} ± 6.17	71.8^{b} ± 7.56	71.2^{b} ± 7.32	74.5^{a} ± 6.62
Juiciness	59.5^{b} ± 10.20	60.8^{ab} ± 9.86	63.4^{a} ± 9.72	60.8^{ab} ± 9.82	60.9^{ab} ± 9.68	63.6^{a} ± 9.34
Firmness	36.3^{a} ± 9.19	34.8^{abc} ± 8.66	32.8^{c} ± 9.66	35.6^{ab} ± 8.98	35.6^{ab} ± 7.73	33.7^{bc}± ± 9.75

$^{a,b\ c}$Rows with different letters differ significantly (P≤0.05); $^{(1)}$ CSOC= cottonseed oilcake

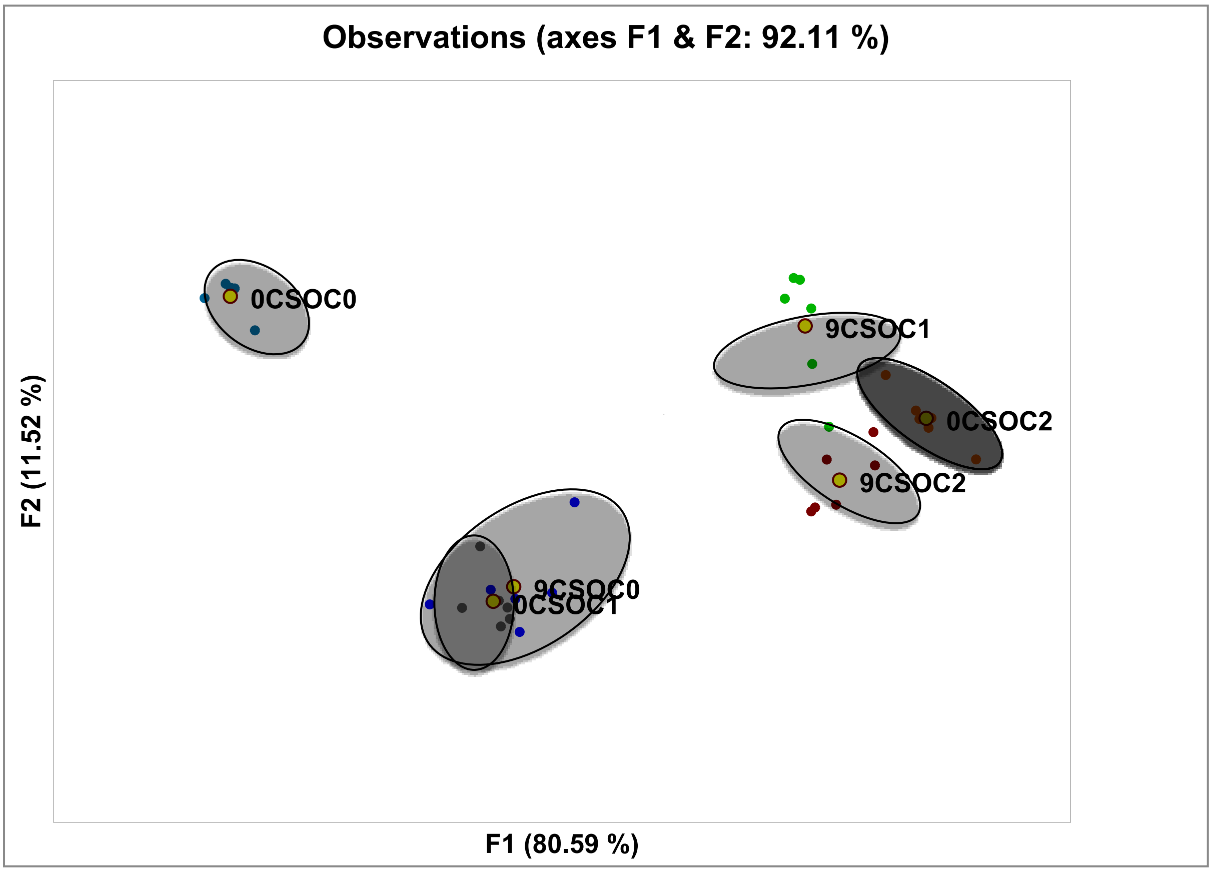
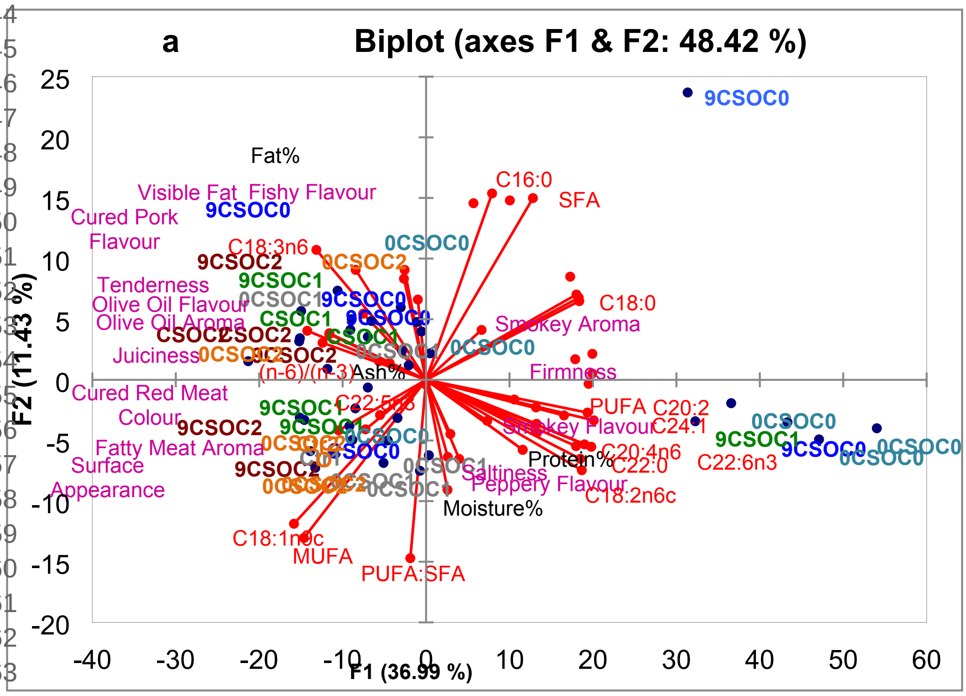


Figure 1: Discriminant Analysis (DA) plot of the fatty acid data for the six treatments of smoked and dried cabanossi.


a
Biplot (axes F1 & F2: 48.42 %)
F1 (36.99 %)
F2 (11.43 %)
Fat%
Visible Fat
Fishy Flavour
Cured Pork Flavour
Tenderness
Olive Oil Flavour
Olive Oil Aroma
Juiciness
Cured Red Meat Colour
Fatty Meat Aroma
Surface Appearance
C16:0
SFA
C18:0
Smokey Aroma
Firmness
C18:3n6
(n-6)/(n-3)
Ash%
PUFA
C20:2
C24:1
C20:4n6
C22:0
C22:6n3
C18:2n6c
Protein%
Saltiness
Peppery Flavour
Moisture%
C18:1n9c
MUFA
PUFA:SFA

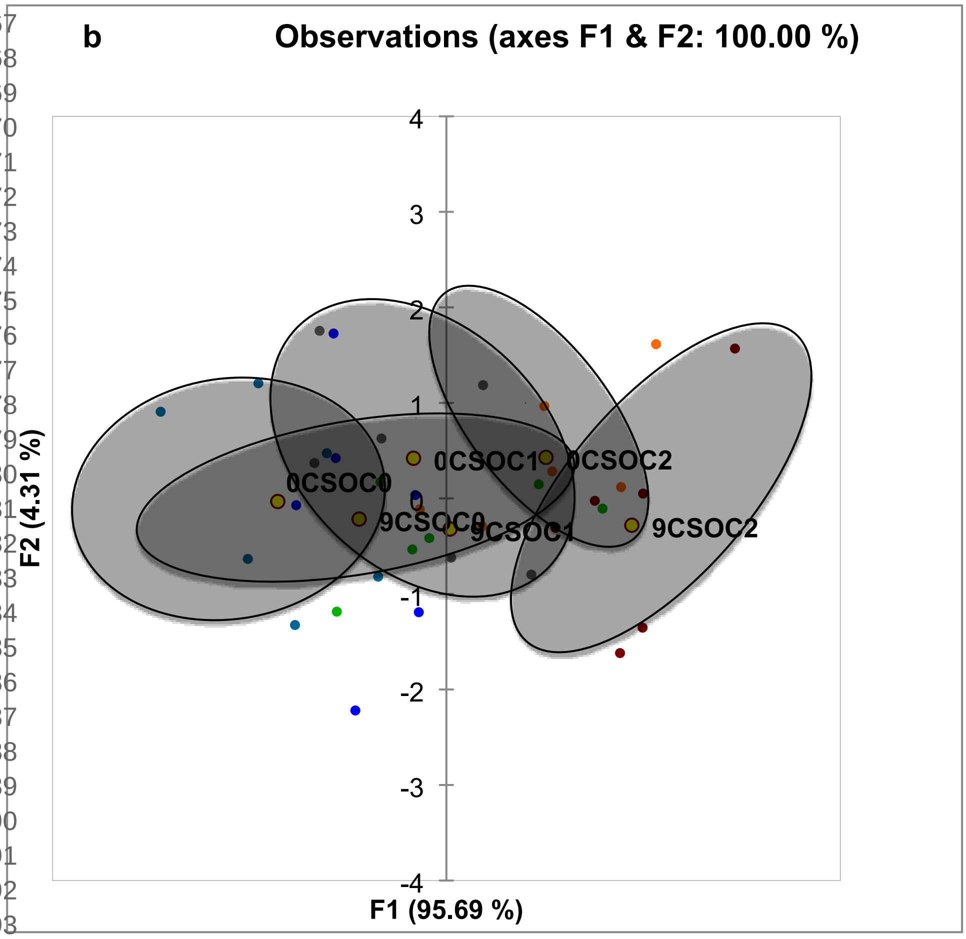

b
Observations (axes F1 & F2: 100.00 %)
F1 (95.69 %)
F2 (4.31 %)
0CSOC0
0CSOC1
0CSOC2
9CSOC0
9CSOC1
9CSOC2

Figure 2 (a) Principle component analysis bi-plot of the sensory attributes, proximate composition and fatty acids (for which there were differences (P≤0.05) noted) of the six respective replications; **(b)** Discriminant analysis plot of the sensory attributes, proximate composition and fatty acid profile.