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Influence of graded level of salt and maturation times on quality traits of beef and pork sun-dried meat: A test pilot

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Abstract

The goal of this study was to assess the qualitative and sensorial characteristics of beef and pork sun-dried meat (SDM) with different salt (NaCl) levels (6%, 8% and 10%) and curing times (30 and 40 h). Samples from the beef strip loin *(Gluteus medius)* and pork loin *(Longissimus thoracic)* were cut to a thickness of 5 cm. Three levels of salt were applied, and the meat was allowed to cure for either 30 or 40 hours with three replications per treatment. The pH, shear force (SF), luminosity (L*), tonality (TON), saturation, loss of water by cooking (LWC), moisture, crude protein (CP), sensory attributes, and consumers' intention to buy were analysed. Beef and pork produced differences in L*, saturation, TON, and CP, appearance, and colour of the sun-dried product. The SDM cured for 30 hours was higher in moisture, LWC and L* (P =0.023), and had greater CP content than that cured for 40 hours. The appearance and salinity of the product were affected by the level of salt that was used in making it. In conclusion, various NaCl levels did not influence the physical-chemical and qualitative characteristics of the SDM, but these characteristics were influenced by the curing and meat type. In addition, the meat type and the salt level affected some aspects of the sensory evaluation.

Keywords: animal protein, dried meat, qualitative characteristics, sensory attributes, sodium chloride levels
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Introduction

Sun-dried meat is a Brazilian product that originated in regions with a predominance of hot and dry weather. Sun-dried meat, dried meat and jerked meat were created as an alternative means of preserving meat owing to the lack of electricity and the low economic level in some parts of northern Brazil (Gouvêa & Gouvêa, 2007). The meat is preserved through treatment with sea salt and dehydration at room temperature in a well-ventilated enclosed space. The meat is protected by tulle-based material and exposed to the early morning sun for 30 minutes to brown the fat meat (Ishihara & Madruga, 2013). It is then left outdoors in a covered well-ventilated place for two to four days. Sun-dried meat differs from dried meat and jerked meat because of its lower NaCl content, shorter maturation time, and greater moisture content (Ishihara & Madruga, 2013; Gouvêa *et al.*, 2016). Cuts such as outside flat and topside, rump steak, knuckle and strip loin from cattle and goats are typically used in its production (Salviano *et al*., 2015). The production of dried meat from pork is less frequent and less studied, despite the high pork production in the region.

Apart from being an alternative method for preserving meat, products such as SDM enable consumers to eat pork and beef products that are manufactured without chemical preservatives and that can be prepared quickly. Improved sensory qualities of the meat, such as tenderness and flavour, greater protein concentration and decreased microbial load, are other attractive features (Gouvêa *et al*., 2016).

The Brazilian Regulation of Industrial and Sanitary Inspection of Products of Animal Origin does not establish a standard of identity, quality, facilities, and manufacturing process of the SDM. Thus, this product is produced mostly by small regional businesses. The NaCl amount and the maturation time required for the physicochemical patterns related to the nutritional, microbiological and sanitary quality of this meat product are not clearly defined. However, Gouvêa & Gouvêa (2007), Lourenço Júnior *et al*. (2015), Salviano *et al*. (2015), Gouvêa *et al.* (2016), Gesteira *et al.* (2019), and others have assessed other dried meat products

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and Park and Lee (2005), Han *et al*. (2007), Yang *et al*. (2009), Ferreira *et al*. (2013), and Adeyeye (2016) evaluated SDM that were similarly derived. Despite these studies there seem to be no scientific studies that evaluated alternative methods for producing dried meat, including curing time and NaCl level, particularly when pork is used.

Because of the lack of guidelines, infrequent use of pork in SDM products and few studies in which SDM was assessed, the goal in this study was to evaluate the qualitative and sensory characteristics of the SDM produced from the bovine strip loin *(Gluteus medius)* and the porcine loin *(Longissimus thoracis)* using various levels of NaCl and curing times. It was speculated that producing SDM with these treatments would improve the sensory attributes and quality of the meat product, as measured by its tenderness, juiciness, and protein content.

Materials and Methods

The experiment was conducted at the Food Technology Laboratory of the Agrarian Sciences Centre of Universidade Estadual do Oeste do Paraná/Unioeste, Campus of Marechal Cândido Rondon, PR, Brazil. The meat was purchased from a local vendor. All experimental procedures were approved by the Unioeste Research Ethics Committee (No. 10/2019 - CEUA).

The SDM processing followed the manufacturing methodology described by Gouvêa and Gouvêa (2007). The 12 kg cuts of bovine strip loin and pork loin were sliced to a standardized thickness of 5 cm. The pH and colour of the fresh meat were recorded. Eighteen samples of beef and pork were used, with each sample weighing 0.313 ± 0.049 kg. To manufacture the SDM, fine iodized cooking salt was applied in two phases. For the first salting, NaCl in the amounts of 5%, 7%, and 9% was applied to the samples. Then the samples were placed in a plastic drainer on plastic trays and allowed to exudate. Ten hours after the first salting, the samples were turned. Then, the second salting was performed with the remainder of NaCl (1%). Ten additional hours after being turned, the samples were hung with nylon clamps until the prescribed curing time had elapsed. In total, the samples were cured at room temperature for 30 or 40 hours in a well-ventilated and enclosed space. The samples were covered with tulle (screen) to avoid contact of insects throughout the process. After the process had been completed, the pH, colour, moisture, LWC, and CP of the samples were recorded.

A portable pH meter (model HI99163, Hanna Instruments, Woonsocket, Rhode Island, USA) was used to measure the meat pH. It was fitted with a meat insertion electrode and calibrated with pH 4.0 and pH 7.0 buffer solutions. At each measurement the electrode was washed with distilled water and dried with absorbent paper (Gomide *et al.*, 2013).

The meat colour evaluation was based on the methodology of Gomide *et al.* (2013). The colouring was measured at three distinct points of the meat sample, that is, at its centre and at the extremities. A colorimeter (model CR-400, Konica Minolta, Chiyoda City, Tokyo, Japan) was used, based on the CIELAB colour system with an aperture of 8 mm, area illumination, illuminant D65 and 0° viewing angle. The light reflectance was measured for luminosity (L*), which ranges from 0 (pure black) to 100 (pure white), and saturation, in which positive *a* (+a) indicates the red and negative *a* (-a) indicates the green, and the positive *b* (+b) indicates the yellow and negative *b* (-b) the blue. To calculate tonality (TON), the equation of Bridi & Silva (2009) was used:

$$\text{Tonality} = \tan^{-1}\left(\frac{a*}{b*}\right)$$

where: $\tan^{-1}$=metric tonality;
a*= red/green coordinate; and
b*= yellow/blue coordinate.

To determine the LWC of the matured SDM, the samples were prepared as steaks of 0.107 ± 0.002 kg each. Immediately after being cured, the samples were grilled in an electric grill preheated to 170 ºC, with non-stick grills covered with perforated aluminium foil, When the internal temperature of the samples reached 40 °C, they were turned over and covered for five minutes, until they reached an internal temperature of 71 °C (Bridi & Silva, 2009). The cooked samples were stored in Styrofoam trays coated with aluminium foil until they reached ambient temperature, refrigerated at 4 °C for 24 hours, and weighed again.

Shear force was recorded using the methodology proposed by Bridi & Silva (2009). The steaks were cored with a cylindrical stainless-steel device that was 1.27 cm in diameter to obtain the four subsamples. Thus, there were 12 subsamples per treatment. Subsamples with a large amount of connective tissue were discarded (Gouvêa *et al.*, 2016). Shear force was measured with a CT3 texture analyser (Brookfield Engineering, Middleboro, Massachusetts, USA) using an inverted 'V' cutting blade. The instrument settings consisted of velocity 5 mm/sec, deformation 20 mm and 10 g force for beef (Ishihara *et al*., 2017); and velocity 2 mm/sec, deformation 20 mm and force of 10 g for pork (Bridi & Silva, 2009).

The moisture content, expressed as a percentage, was determined as the ratio of the weight of the fresh meat to the weight of the SDM sample that was made from it. Crude protein was measured using the micro-Kjeldahl method. To determine total nitrogen content (Silva & Queiroz, 2002) the fresh samples were ground in a meat processor. From each sample a portion of 2.00 g was used in the analysis.

A hedonic five-point scale was used for sensory analysis. The evaluation panel consisted of 27 untrained tasters, including students, professors, and employees of various age groups. The tasters were not accustomed to consuming SDM. The sensory analysis was conducted at Unioeste Food Technology Laboratory. The samples were identified by symbols to avoid preconceived bias on the part of the tasters. A maximum of four tasters at a time evaluated the products independently. The samples were cooked on an electric grill at 170 °C without desalting or adding water, cut into cubes of approximately 2 cm, placed in plastic cups identified with simple symbols, and stored in a thermal box. To remove the residual flavour between samples, crackers and water were provided. The tasters evaluated appearance, colour, aroma, flavour, texture, juiciness and salinity, using scores from 1 to 5 (1, bad; 2, regular; 3, good; 4, very good; 5, excellent). Intention to buy and buyer satisfaction were scored similarly (1, would never buy/dissatisfied; 2, would seldom buy /slightly dissatisfied; 3, would buy occasionally/indifferent; 4, would buy frequently/satisfied; and 5, would always buy/very satisfied).

The experiment was a randomized complete block design with 12 treatments and three replications. The quantitative and sensorial data were submitted to variance analysis according to the statistical model:

$$Y_{ijlk} = \mu + \alpha_i + \alpha_j + \beta_l + (\alpha\beta)_{ijl} + \varepsilon_{ijlk},$$

where Y_{ijlk} = average observation of a dependent variable that was treated with the ith NaCl level (α_i), cured for the jth length of time (α_j), made from lth meat type (β_l), and in the kth replication; with μ denoting the overall mean and $(\alpha\beta)_{ijl}$ denoting the interaction of the treatment effects. The ε_{ijlk} was the random residual error. For the sensory analysis, the scores of the individual tasters were averaged to obtain one score for each sample. The indications of sample preference were summarized as frequencies. Significance was declared with $P \leq 0.05$. The effects with $0.05 < P \leq 0.10$ were deemed a tendency. Treatment means were compared using Tukey's test. Normality of the residuals was tested with Shapiro-Wilk's test. Values that were three or more standard deviations from the mean were considered outliers. Homogeneity of variance was tested by the Bartlett's test. All analyses were performed by the statistical program R Core Team (2019).

Results and Discussion

Treatments had no significant effect ($P > 0.05$) on the SF and pH attributes (Table 1). As expected, the difference between beef and pork influenced ($P < 0.01$) the CP, L*, a*, b* and the tonality of SDM. Moisture ($P < 0.05$), LWC ($P < 0.01$), and luminosity ($P < 0.05$) were reduced with the longer curing time whereas the CP ($P < 0.01$) concentration became greater as the SDM became drier. NaCl levels influenced ($P < 0.01$) the concentration of CP in the SDM with the intermediate level of salt having the lowest CP content.

No prior studies were found of SDM made from pork. The differences between pork and beef might result from the proportion of red muscle fibres (slow contraction and oxidative) being higher in cattle and white muscle fibres (fast contraction and glycolytic) being higher in pigs (Bee *et al*., 2006). The L* of beef is less than pork because lighter coloured material is expected to reflect more light. Another factor that could promote differences in colour of meat is protein denaturation, which can result from heating or the addition of salt (Bircan & Barringer, 2002; Ishiwatari *et al.*, 2013; Yu *et al.*, 2016). These changes occur through electrostatic interactions or osmotic disturbance o the protein structure (Sinha & Khare, 2014).

The average values of moisture and pH were similar to those reported by Nascimento *et al*. (2018) in an experiment with beef SDM, namely 57.64% and 5.8%, respectively, However, Gurgel *et al*. (2014) obtained higher pH values for beef SDM (5.8% to 6.0%). Ferreira et al. (2013), obtained a 13.4% greater pH in pork cured with 10% NaCl level compared with the present study (5.9% vs 5.2%). According to Costa-Corredor *et al*. (2010), the initial pH of the meat affects the ion absorption during the salting process and not afterwards, because there is a change in the ratio of some ions such as sodium and potassium. In addition, a reduction in pH may inhibit and reduce the growth of several microorganisms and the consequent deterioration of meat products. In this way, an increase in pH could decrease the protein level of SDM.

Changes in coloration are expected during maturation because of proteolytic activity in the cellular structure of the meat. These changes can reduce the capacity to retain water, which contributes to increased light reflection from the cut surface of the meat (Huff-Lonergan *et al*., 2005). The meat colour is affected directly by its water content, and water retention is influenced by the pH, thus altering the ability of the surface structure to absorb or reflect the light (Gouvêa *et al*., 2016). Ferreira et al. (2013) reported higher L* in pork when including 10% NaCl, a result that differs from the present study. These authors explained that

Table 1 Average values of physicochemical and qualitative characteristics assessed in sun-dried meat as affected by meat type, drying time, and salt level

Item	Meat type		Time, hours		Salt levels, %			SD	*P-value*			
	Beef	Pork	30	40	6	8	10		MT	Time	Salt	Interaction
Moisture, %	52.03	56.68	58.06[a]	50.47[b]	56.21	54.15	53.31	8.45	0.052	0.007	0.555	0.820
Shear force, N	19.81	19.02	19.91	18.93	19.22	19.81	19.12	39.56	0.546	0.461	0.895	0.298
pH	5.24	5.23	5.24	5.23	5.24	5.23	5.22	0.07	0.560	0.560	0.842	0.654
LWC, %	9.52	9.97	11.51[a]	7.97[b]	9.84	9.84	9.54	3.05	0.626	<0.001	0.952	0.747
Crude protein, %	23.18[b]	23.97[a]	22.79[b]	24.37[a]	24.34[a]	22.28[c]	24.11[b]	1.75	<0.001	<0.001	<0.001	<0.001
L*	30.02[b]	37.62[a]	34.65[a]	32.99[b]	33.5	34.27	33.68	4.47	<0.001	0.023	0.643	0.160
a*	7.62[a]	2.55[b]	5.11	5.06	5.37	5.22	4.67	2.72	<0.001	0.879	0.128	0.387
b*	6.16[a]	4.73[b]	5.27	5.61	5.58	5.40	5.35	1.25	<0.001	0.342	0.862	0.556
Tonality	5.14[a]	3.85[b]	4.39	4.60	4.70	4.48	4.31	0.81	<0.001	0.159	0.096	0.097

[a,b,c] Within an effect means with a common superscript were not different with probability *P* =0.05
MT: meat type, LWC: loss of water by cooking, L*: luminosity, a*: red intensity, b*: yellow intensity

the colour parameters depended on factors such as chemical reactions during processing and the concentration of myoglobin. The intensities of red and yellow colour were higher in the beef samples, indicating more oxidized myoglobin or oxy-myoglobin and met-myoglobin as a product of the higher myoglobin content of the muscle. Myoglobin and haemoglobin are composed mostly of proteins. Myoglobin is the muscle pigment that retains oxygen and haemoglobin is responsible for the transport of oxygen in the bloodstream. Thus, meat colour indicates the myoglobin concentration and the oxygenation or oxidation on the surface of the muscle. Myoglobin content is known to vary with species, sex, age, anatomical location of the muscle, physical activity, muscle fibre type and blood loss of the animal at slaughter (Cornforth, 1994). In addition, the colour change in samples can be affected by sampling time and ambient temperature because they affect the kinetics of chemical reactions (Bampi *et al.*, 2019). Moisture was reduced from 58.06% to 50.47% and CP increased from 22.79% to 24.37% with maturation time, which may indicate an improvement in the quality (Gouvêa *et al.*, 2016; Salviano *et al.*, 2015). The phenomenon is known as salting out, as the salt draws water molecules out of the cells by osmosis. As the water flows from the meat during curing, its CP content increases with time (Garcia *et al.*, 2013). These findings were in agreement with Gouvêa *et al*. (2016).

In addition, salt draws moisture from microorganisms, also by osmosis, and reduces their viability. This highlights a need for regulation and standardization of the use of NaCl in SDM production. Using salt in the production of SDM provides greater control of unwanted microorganisms and reduces the presence of *faecal coliforms* which might be present as a result of poor hygiene of the workers and cleanliness of the production environment (Decree number 10.468/2020). The NaCl can also solubilize and extract myofibrillar proteins from meat, and these processes can contribute to fat emulsification and increased water retention capacity, reducing LWC and thus contributing to improved product quality (Gouvêa *et al*., 2016).

One of the most important attributes of SDM is its decreased hardness, which is affected by moisture content and measured with SF (Yang *et al*., 2009). Shear force values can be used to characterize processed meat products, measure the force required for the SDM sample to rupture, and are related to the tenderness of the product (Lim *et al*., 2014). Choi *et al.* (2016) reported SF values of 43.74 Newtons (N) in cured pork loin with an average salinity of 3.25%. In the present study, all treatments produced products that were classified as tender with SF values lower than the 31.38 N threshold specified by Belew *et al*. (2003). Souza (2005) reported higher values (62.78 N), using 3% NaCl, with additional sodium lactate and sodium diacetate which may have had a negative influence on the tenderness of the processed meat. According to Choi *et al.* (2016), NaCl levels increased SF in meats owing to myofibrillar proteins showing increased binding strength. This may occur due to action of enzymes such as calpain and calpastatin, which hydrolyse myofibrillar proteins during the meat maturation process and alter meat tenderness (Andrighetto *et al*., 2006).

The tasters preferred and were more likely to buy beef SDM than pork (Figure 1). The SDM that was cured for 30 hours was preferred by the tasters. Finally, the 6% level of NaCl produced the preferred

product, followed by the median level of 8%, with the fewest tasters indicating a preference for the product made with the highest level of NaCl. However, because it is an uncommon product in the study region, pork SDM showed a reasonable level of acceptance by the tasters. Satisfaction for both meat types was high. The curing time of 30 hours had the highest score for intention to buy and product satisfaction.

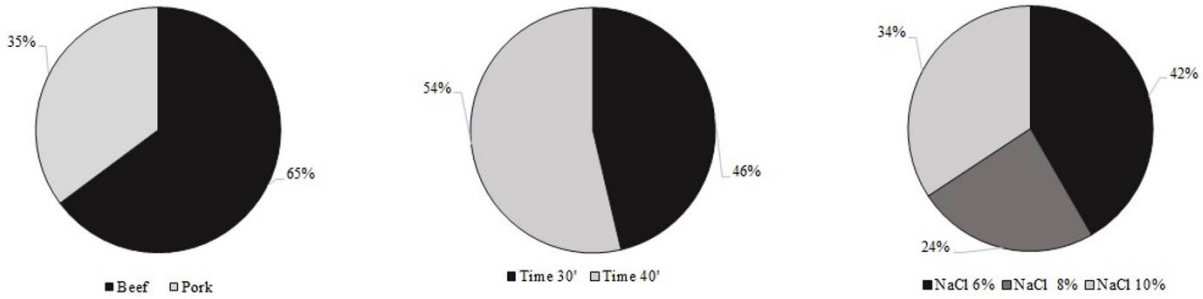


Figure 1 Preference of tasters for sun dried meat made from beef and pork, cured for 30 or 40 hours, and produced with three levels of salt

Among the samples, some were preferred by the tasters (Figure 2). The beef samples represented five of the eight preferred samples. Samples of beef that were produced with 6% NaCl had a higher preference (37%), followed by the beef produced with a higher level of NaCl and cured for 40 hours (18.5%). The pork SDM cured for 30 hours and with the higher levels of NaCl had a preference of 18.5% of tasters, indicating that there was no need to desalt the product. The pork SDM produced with the highest level of NaCl (10%) and longest curing time (40 hours) was preferred by 11.1% of the tasters.

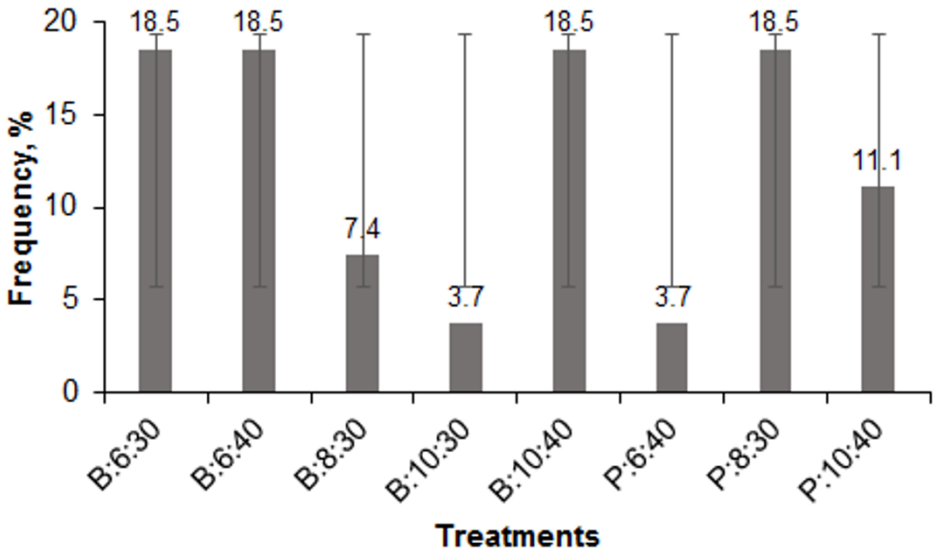


Figure 2 Frequency with which the tasters identified the samples of sun-dried beef as being most preferred

B: beef, P: pork, 6: 6% NaCl; 8: 8% NaCl; 10 = 10% NaCl, 30: cured 30 hours, 40: cured 40 hours

The tasters accepted SDM of both meat types but preferred beef, although some indicated that they preferred pork. Thus, both types of SDM have a high potential for acceptance and is a possible market for products cured for various lengths of time. The NaCl levels used in producing the SDM had little influence on their sensory characteristics. However, the preference evaluation by the tasters was clear since most of them disliked products produced with 10% NaCl. This raised the possibility of desalting these less preferred products, Choi *et al.* (2016) found that the flavour and overall acceptability scores of products made with

refined salt (salinity of 3.25%) was greater than those of solar (salinity of 2.89%) and bamboo (salinity of 3.00%) salt.

There were no effects (P >0.05) of meat type, time and NaCl level on aroma, flavour, texture, and juiciness (Table 2). However, NaCl levels affected appearance (P =0.013) and salinity (P =0.002). Although consumers preferred lower salt concentrations in both types of SDM, this effect did not impinge on its flavour.

Table 2 Average values from the sensory assessment of sun-dried meat as affected by meat type, drying time, and salt level

Item	Meat type		Time, hours		Salt levels, %			SD	*P*-value			
	Beef	Pork	30'	40'	6	8	10		MT	Time	Salt	Interaction
Appearance	3.87[a]	3.46[b]	3.68	3.64	3.97[a]	3.41[b]	3.61[ab]	0.842	0.011	0.764	0.013	0.867
Colour	3.85[a]	3.37[b]	3.62	3.59	3.72	3.38	3.72	0.806	0.001	0.724	0.067	0.704
Aroma	3.57	3.44	3.40	3.61	3.58	3.47	3.47	0.837	0.430	0.262	0.749	0.683
Flavour	3.79	3.42	3.72	3.5	3.66	3.50	3.66	1.100	0.069	0.184	0.351	0.243
Texture	3.81	3.72	3.61	3.92	3.91	3.52	3.86	0.881	0.576	0.073	0.080	0.290
Juiciness	3.83	3.61	3.59	3.85	3.77	3.63	3.75	0.935	0.212	0.170	0.687	0.162
Salinity	3.57	3.29	3.48	3.38	3.94[a]	3.36[b]	3.00[b]	1.162	0.189	0.528	0.002	0.601

[a,b,c] Within an effect means with a common superscript were not different with probability P =0.05
MT: meat type

Many factors influence the desirability of cured meat products. Purriños *et al.* (2011) found no differences in the sensory attributes of appearance, odour, flavour, and texture when investigating the influence of salt content in cured pork from the foreleg of the pig. However, the salinity score showed differences in the salt levels (14% to 20%). Ferreira *et al*. (2013) found no changes in pork texture with the addition of various levels of NaCl. According to Pearce *et al*. (2011), several attributes of meat quality are related to its moisture content, in other words, the distribution and mobility of water in muscle and meat influences juiciness, tenderness, firmness and appearance. In addition, other characteristics also affect meat quality, including breed, age, sex, muscle type, technological processing, handling, and feeding (Huidobro *et al*., 2005).

The Brazilian tradition of consuming salted and dried meat remains current. Thus, it is necessary to develop new processing and drying technologies for producing SDM based on scientific knowledge. When scientific knowledge about SDM has been disseminated, the consolidation of the chain of production chain can occur. In Brazil, SDM is a hand-crafted product in the northern regions. The absence of production specifications and formalized marketing strategies limits wider acceptance of this product.

Conclusions

Sun dried meat is an alternative to the processing, drying, preserving, and consuming beef and pork with growing consumer interest. Producers of SDM need to be cognizant of the meat that is used in their product and the time the product is allowed to cure. The level of NaCl used in its production is of lesser importance, as long as it is sufficient.

Authors' Contributions

All the authors contributed equally and commented on the early and final version of the manuscript.

Conflict of Interest Declaration

The authors confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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