Impact of different storage temperatures on canned meat Characteristics

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Abstract

The aims of this study are determination the change of chemical traits for canned meat tuna storage at different temperatures for different periods.

A total number of 56 samples of canned tuna meat products by Iran was collected from Sulaimani city markets.

Different indicators were measured (pH, Total volatile base nitrogen, Free fatty acids, and Thiobarbaturic acids), to determine chemical traits in canned meat tuna stored in 3 different storage temperature (5, 15, and 25 ˚C) and stored for 120 days, and comparing them with the acceptable limits for each trait. All tests were made in the post-graduate laboratories of the Animal Sciences Department, College of Agricultural Engineering Sciences, University of Sulaimani, Kurdistan Region, Iraq, from November 2020 to the end of February 2021 (4 months).

this study examined the effects of temperature and duration of storage on pH, TBA, TVN, and FFA in canned meat tuna. There was a significant increase ($P \leq 0.05$) in pH, TBA, TVN, and FFA for tuna sample types during storage, the highest pH value in tuna, after 120 days was (8.500) when the canned meat storage at (25˚c), in addition,

TBA value for canned tuna, the highest TBA values recorded in Tuna meat from treatment 3(25˚c) (2.301 mg MDA/ kg meat) in 120 days, also, the highest TVN value in tuna, after 120 days was (19.855 mg N/ 100g meat) when the canned meat storage at (25˚c), on the other hand, the highest FFA percentage in tuna after 120 days was (2.580) when the canned meat storage at (25˚c). the values of chemical indicators within the standard limits.

Keywords: Storage temperature, Chemical indicators, Canned meat tuna

Introduction

Canning meat, poultry, game, and fish is a great way to preserve quality sources of protein. When properly preserved, homemade canned goods are safe, tender, and tasty. Only utilize meat, poultry, game, and fish that have been trimmed of any gristle, bruised places, or fat to ensure high quality. Chill immediately after slaughtering home-produced meat to avoid spoilage. When meat is cold, it is easier to handle. Keep meat at a temperature below 40°F until ready to can it; can it within a few days of slaughter, for a thorough chilling. If you need to keep meat for more than a few days, freeze it first. Until canning time, keep frozen meat at a temperature of 0°F or lower. If you want to thaw frozen meat before canning it, do so in the refrigerator at 40°F or below until most of the ice crystals have vanished. Canned meat is an emulsion-type, heat-sterilized cured meat product with a shelf life of around three years at room temperature. (Standard 1998)

Canned goods, despite their thermal processing, are prone to microbial deterioration. Spoilage is produced by

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the proliferation of microorganisms that have been contaminated by a leak or under-processing. (Warren 1998)

The canning the process has been reported to alter the proximate composition percent lipid, some increase in percent protein, and a significant decrease in percent moisture (García-Arias et al. 2004)

Meat preservation became crucial after the advent and quick growth of supermarkets, as it allowed the meat to be transported over long distances without losing its texture, color, or nutritional value.(Nychas et al. 2008). Preservation techniques aim to limit oxidation and enzymatic degradation while also preventing microbiological contamination (self-autolysis).(Nychas et al. 2008)

Meat rotting is caused by three primary mechanisms: microbial growth, oxidation, and enzymatic autolysis. Pre-slaughter husbandry practices, the age of the animal at the time of slaughtering, handling during slaughtering, evisceration, and processing, temperature controls during slaughtering, processing, and distribution, preservation methods, type of packaging, and consumer handling and storage are all factors that influence microbial growth and metabolism. (Cerveny et al. 2009). pH changes, slime development, structural component breakdown, off-odors, and appearance changes are all symptoms of microbial spoilage. Natural processes such as lipid oxidation and the generation of free radicals influence fatty acids, causing oxidative degradation of meat and the creation of off-flavors. In meat, lipid hydrolysis can occur either enzymatically or non-enzymatically. Enzymatic reactions occur spontaneously in the muscle cells of slaughtered animals, and they act as catalysts for chemical reactions that eventually result in meat self-deteriorate(Enser et al. 2001; Simitzis et al. 2010). The tissue decomposition of complex molecules (carbohydrates, lipids, and protein) in the autolysis process causes softening and greenish coloring of the flesh. (Kanner 1994)

this study aims to determine the change of chemical traits, for some canned meat (tuna) storage at different temperatures for different periods.

Material and methods

Sampling

Samples of tuna canned meat, is most commercially available in the Sulaimani governorate. After opening the container, we will estimate the quality of meat and then stored it at 3 different storage temperature (5, 15, and 25 ˚C) and stored for 120 days, the measurements taken place at (0 ,15,30,60,90 and 120) day.

Chemical indicators

pH

Samples (5 g) are homogenizing in 45 mL of distilled water using a grinder for 1 min. Sample solutions are centrifuge for 15 min at 2,000 g, and the pH is measure using a pH meter. The pH of frozen beef is measure just after thawing

Total volatile nitrogen (T.V.N) (Malle and Poumeyrol, 1989) modified

Fifty gm of the minced sample were mixed for 1min with 100 ml of 7.5%

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Trichloroacetic acid (TCA) in a blender. The mixture was filtered and 12.5 ml of the filtrate was transferred to macro-Kjeldahl distillation apparatus of 125 ml capacity, then 2.5 ml of 10 % NaOH solution were added to the distillation which was carried out, and the distillate was collected in 7.5 ml of 4% boric acid. The distillate was titrated with 0.05 N H_2SO4, using methyl red –bromocresol green as an indicator. The blank was carried out using 25 ml of 7.5% Trichloroacetic acid instead of the meat sample. The TVN. value was estimated as follows:

$$\text{TVN (mg N/100gm)} = \frac{V \times 14 \times (100+M/100 \times 100)}{12.5 \times 50}$$

Where: V=ml of 0.05 0f H_2 SO_4, M=moisture content

Thiobarbaturic Acid (TBA)

The lipid oxidation value of meat canning samples is determined using TBARS according to the method described by(Xia et al. 2012) with slight modifications. 10 g of each meat canning sample is weight out and homogenize. Then, 50 mL of 7.5% (w/v) trichloroacetic acid (TCA) solution is added and the mixture is a vortex for 30 min. The sample solution is filtered through Whatman No.1 filter paper, and then 5 mL of 20 mM 2-thiobarbituric acid is added and the mixture is boiled in a water bath for 40 min.

The sample is cool to 20-25oC for 30 min and centrifuged at 5500 rpm and 25 oC for 25 min. The absorbance of the supernatant is measure at 532 nm. The TBARS values are express as mg malonaldehyde/kg sample (mg MA/kg) and calculated as follows:

TBARS (mg MA/ kg) = (A532/Ws) × 9.48

Ws is the sample weight, and A532 is the absorbance of the test solution at 532 nm (g), and 9.48 is a constant derived from the dilution factor and the molar extinction coefficient (152,000 L mol -1 cm-1) of the red TBA product.

Free fatty acids (FFA) (Egan *et al.*, 1981)

Weights of 10 gm of the sample were placed in a mechanical blender and 25ml of chloroform was added, the mixture was blended for 2-3 min and filtered immediately through a large filter paper. This was then re-filtered through a paper containing a small amount of anhydrous sodium sulfate. Portions of the filtrate were used for the determination of free fatty acids as follows:

Five ml of 95% ethanol neutralized with drops of 0.1 N NaOH after adding phenolphthalein. The solution was added to 5 ml of the filtered and the mixture tittered with 0.1 N NaOH until the pink colour persists for 15 seconds. The FFA calculates as oleic acid as percentage of the sample:

$$\text{Free fatty acid (FFA.) \%} = \frac{ml\ of\ 0.1\ NaoH \times 0.0282 \times dilution\ factor}{sample\ weight}$$

$$\frac{\text{ml of 0.1 NaoH} \times 0.0282 \times \text{dilution factor}}{\text{sample weight}} \times 100$$

Statistical Analysis

The statistical analysis system XLSTAT (2016) program was used to analyse the data obtained study. Factorial Complete Randomized Design (CRD), was used to analysis data using that the following liner additive model:

$$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\ \beta)_{ij} + e_{ijk}$$

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μ = The overall means of traits.

α_i = The effect of temperature factor (i = 1, 2)

β_j = The effect of storage periods

$(\alpha\ \beta)_{ij}$ = The effect of interaction between temperature and storage periods

e_{ijk} = Random error, assumed to be equal to zero and variance is σ^2_e (N~ 0, σ^2_e)

The significance of differences between means of traits were determined using Duncan's multiple range tests under the probability ($P< 0.05$) Duncan (1955). Data of all percentages were transformed to arcsine before statistical analysis.

RESULTS AND DISCUSSION

pH in tuna canned meat

The results in Table (1) showed that there are significant differ (P<0.05) in Tuna meat pH values in different treatments and different periods , in 0 days , the pH values in meat from treatment 3 (25˚c) differed significantly (P<0.05) from pH values in meat from treatments 1 (5˚c) and 2(15˚c), the highest values recorded in meat from treatment 3(25˚c), it was(6.892) while the lowest values recorded in treatment 1(5˚c) (6.482), in 15 days of storage , the pH values in treatment 1(5˚c) differed significantly (P<0.05) from pH values in meat from treatments 2 (15˚c) and 3(25˚c), the highest values recorded in meat from treatment 2 (15˚c), it was (6.700) while the lowest values recorded in meat from treatment 1(5˚c), it was (6.267), in 30,60,and 90 days of storage , the pH values, not differ significantly (P<0.05), in 120 days , the pH values in meat from treatment 3(25˚c)differed significantly(P<0.05) from pH values in meat from treatments 1(5˚c) and 2(25˚c), the highest values recorded in meat from treatment 3(25˚c) (8.500) while the lowest values recorded in meat from treatment 1(5˚c) (7.500),

The highest pH values recorded in meat from treatment 3(25˚c) at 120 days of storage, while the lowest values recorded in meat from treatment 1(5˚c) at 15 days of storage.

The pH values in our experiment correspond with Fatma Arfat (1994) results**,** which observed that pH values of canned sardine and mackerel products were increased during storage at room temperature due to protein degradation into basic products such as ammonia, amines, and hydrogen sulfide. (El Lahamy 2020) Studied the effect of storage period on the quality of canned chela (*Laubuka dadiburjori*) and found that the pH value were 5.9, 6, and 6.2 for 0, 30, and 60 days of storage period respectively In addition ,The reduction of pH value also reported by (El-Sherif 2001), the higher pH values observed in canned samples may be due to the formation and accumulation of some dibasic amino acid and volatile basic nitrogenous compounds such as NH_3 as a result of breakdown and proteolysis of proteins during heat treatment.

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Table 1: pH Mean value of the Tuna meat storage at different temperature for 120 days (mean± standard error).

Treatment	Period(day)					
	0	15	30	60	90	120
T1(5˚c)	6.482±0.059 gh	6.267± 0.000 h	6.733±0.050 fg	7.333±0.050 bcd	7.400±0.050 bc	7.500±0.050 bc
T2(15˚c)	6.601 ±0.001 fg	6.700 ±0.050 fg	6.700±0.050 fg	7.267±0.050 cd	7.367±0.050 bcd	7.633±0.000 b
T3(25˚c)	6.892±0.281 ef	6.633±0.000 fg	6.600 ±0.050 fg	7.067±0.050 de	7.233±0.100 cd	8.500±0.500 a

Means with different letter are significant differ ((P<0.05)

Thiobarbaturic Acid (TBA) in Tuna canned meat

The results in Table (2) clarify that there are significant differ (P<0.05) in Tuna meat TBA value in different treatments and different periods, in 0 days , the TBA value in Tuna meat for treatment 3(25˚c) differed significantly (P<0.05) from TBA value in Tuna meat for treatments 1 (5˚c)and 2(15˚c), the highest value recorded in meat from treatment 3(25˚c) (0.437 mg MDA/kg) while the lowest value recorded in Tuna meat from treatment 2(15˚c) (0.114 mg MDA/kg)., in 15,30,60,and 90 days , the TBA value, not differ significantly, in 120 days of storage the T.B.A values in Tuna meat from treatment 3(25˚c) differed significantly (P<0.05) from TBA values in Tuna meat from treatment 1(5˚c)and 2(15˚c),the highest values recorded in Tuna meat from treatment 3(25˚c) (2.301 mg MDA/kg) while the lowest values recorded in Tuna meat for treatment 1(5˚c) (0.731 mg MDA/kg)

The highest TBA values recorded in Tuna meat for treatment 3(25˚c) in 120 days of storage, while the lowest values recorded in Tuna meat for treatment 2(15˚c) from 0 days.

The result of our experiment is consistent with (Selmi et al. 2008) who studied the effect of the local canning process and storage time (up to 6 months) on tuna in olive oil and tomato sauce and found that the TBA index increased significantly in tuna. This may be to that increase TBA values in meat during storage might occur due to oxidation of fats rich in unsaturated fatty acids (Hedrick 1994)

In general, inspected canned meat fish and storage for 120 days was with the limits regulated by (ICOSQC, 1987) who specified the TBA should not exceed more than 5 mg MDA/ kg meat.

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Table 2: TBA Mean Values (mg MDA/ kg meat) of the Tuna meat storage at different temperature for 120 days (mean± standard error).

Treatment	Period (day)					
	0	15	30	60	90	120
T1(5˚c)	0.418±0.033 ef	0.545±0.151 cde	0.578±0.070 cde	0.607±0.044 cde	0.674±0.028 bcde	0.731±0.182 bcde
T2(15˚c)	0.114±0.047 f	0.468±0.017 de	0.580±0.027 cde	0.650±0.115 bcde	0.622±0.127 bcde	0.937±0.085 b
T3(25˚c)	0.437±0.016 e	0.480±0.023 de	0.664±0.164 bcde	0.782±0.069 bcd	0.854±0.070 bc	2.301±0.280 a

Means with different letter are significant differ ((P<0.05)

Total volatile basic nitrogen (TVN) in Tuna Canned meat

The results in Table (3) showed that there are significant differ (P<0.05) in Tuna meat T.V.N values in different treatments and different periods, in 0,15 and 30 days , the T.V.N values, not differ significantly(P<0.05), in 60 days of storage , the T.V.N values in Tuna meat from treatment 2(15˚c) differed significantly (P<0.05) from T.V.N values in Tuna meat from treatments 1(5˚c) and 3(25˚c) the highest values recorded in Tuna meat from treatment 3(25˚c) (14.801 mg N/ 100 gm meat) while the lowest values recorded in Tuna meat from treatment 2(15˚c) (7.690 mg N/ 100 gm meat), in 90 days of storage , the T.V.N values in Tuna meat from treatment 2(15˚c) differed significantly(P<0.05) from T.V.N values in Tuna meat from treatments 1(5˚c)and 3(25˚c), the highest values recorded in Tuna meat from treatment 1(5˚c) (19.855 mg N/ 100 gm meat) while the lowest values recorded in Tuna meat from treatment 2(15˚c) (11.811 mg N/ 100 gm meat), in 120 days of storage , the T.V.N values in Tuna meat from treatment 2(15˚c) differed significantly (P<0.05) from T.V.N values in Tuna meat from treatments 1(5˚c)and 3(25˚c), the highest values recorded in Tuna meat from treatment 1(5˚c) (19.855 mg N/ 100 gm meat) while the lowest values recorded in Tuna meat from treatment 2 (15˚c) (11.811 mg N/ 100 gm meat).

The highest T.V.N values recorded in Tuna meat from treatment 1(5˚c) after 90 and 120 days of storage, while the lowest values recorded in Tuna meat from treatment 2(15˚c)) from 60 days of storage.

The increase in the TVN values of meat sample is agreement with (Mawlood and Khidhir 2018) results, that have found that TVN value increase during storage time in meat during 90 days of storage at -18 °C. On the other hand, these studies referred to an increase in TVN during the storage period to different degrees, depending on different factors such as temperature, storage period, and meat type. There are many studies have done on different storage meat in which the TVN had been followed as an indicator for the storage meat sample type (Rukchon et al. 2011).

The TVN values in samples taken from canned meat fish and stored at different temperatures for 120 days are acceptable according to Iraqi standardization. The

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Iraqi Central Organization for Standardization and quality control, IQS 1179, specified the canned meat fish TVN. value not to exceed 20 mg N/ 100g meat (ICOSQC; 1987).

Table 3: T.V.N Mean values (mg N/ 100g meat) of the Tuna meat storage at different temperature for 120 days (mean± standard error).

Treatment	Period(day)					
	0	15	30	60	90	120
T1(5˚c)	13.330±0.842 bcde	10.137±0.802 bcde	8.905±0.780 cde	13.557±0.770 abcde	19.855±5.536 a	19.855±5.536 a
T2(15˚c)	15.115±1.222 abc	8.698±2.630 cde	13.335±0.900 bcde	7.690±2.313 e	11.811±0.353 bcde	11.811±0.353 bcde
T3(25˚c)	11.270±0.479 bcde	9.725±0.330 bcde	8.541±0.367 de	14.801±0.769 abcd	15.950±2.524 ab	15.950±2.524 ab

Means with different letter are significant differ ((P<0.05)

Free Fatty Acids (FFA) in Tuna Canned meat

The results in Table (4) explain that there are significant differ (P<0.05) in Tuna meat FFA percentages in different treatments and different periods, in 0,15 and 60 days , the FFA percentages , not differ significantly(P<0.05), in 30 days of storage , the FFA percentages in Tuna meat from treatment 3 (25˚c) differed significantly (P<0.05) from FFA percentages in Tuna meat from treatments 1(5˚c) and 2(15˚c), the highest values recorded in Tuna meat for treatment 3(25˚c), it was (1.666%), while the lowest percentages recorded in Tuna meat for treatment 1(5˚c), it was (0.727%), in 90 days of storage , the FFA percentages in Tuna meat for treatment 2(15˚c) differed significantly (P<0.05) from FFA values in Tuna meat from treatments 1(5˚c)and 3(25˚c), the highest percentages recorded in Tuna meat from treatment 3(25˚c), it was (2.476%) while the lowest percentages recorded in Tuna meat from treatment 2(15˚c), it was (0.993%), in 120 days of storage , the FFA percentages in Tuna meat from treatment 3(25˚c) differed significantly (P<0.05) from F.F.A percentages in Tuna meat from treatments 1(5˚c)and 2(15˚c),the highest values recorded in Tuna meat from treatment 3(25˚c), it was (2.580%) while the lowest percentages recorded in Tuna meat from treatment 1(5˚c), it was(1.034%).

The highest FFA values recorded in Tuna meat from treatment 3(25˚c) after 120 days of storage, while the lowest values recorded in Tuna meat from treatment 1(5˚c) at 0 days.

The FFA values in our experiment correspond with(Asgharzadeh et al. 2010) results, who found the FFA values increased with increasing

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storage
time, FFA percentages registered in silver carp was (6.6) at 0 days, while F.F.A percentages recorded in silver carp was (14.1) after 6 months of storage, Also
the formation of FFA itself does not lead to nutritional losses, its assessme nt is deemed important when consider ing the development of rancidity.
Thus, apro-oxidant effect of FFA on lipid
matter has been proposed and explain ed on the basis of a catalytic effect of the carboxyl group on the
formation of free radicals by the decomposition of hydroperoxides(Yoshida et al. 1992; Aubourg 2001). On o the other hand , FFA has shown to interact with pro teins leading to fish texture deterioration during frozen storage (Mackie 1993). in addition, The F.F.A results of our study near to results of F.F.A percentages in the study of (Maheswara et al. 2011) that the initial FFA content of freshly prepared canned tuna was (0.7%) and increased to (6.50%).
At the storage canned meat fish for 120 days, the present results were within the acceptable limits according to APHIS & FDA (2008) because there are below than 3%. For ICOSQC (1987.

Table 4: FFA Mean (%) of the Tuna meat storage at different temperature for 120 days (mean± standard error).

Treatment	Period (day)					
	0	15	30	60	90	120
T1(5˚c)	0.240±0.062 e	0.715±0.180 de	0.727±0.217 de	0.884±0.104 de	1.738±0.425 b	1.034±0.172 cd
T2(15˚c)	0.465±0.115 de	0.778±0.253 de	0.845±0.161 de	0.874±0.398 de	0.993±0.078 d	1.696±0.138 bc
T3(25˚c)	0.544±0.105 de	0.822±0.057 de	1.666±0.069 bc	0.961±0.316 de	2.476±0.375 a	2.580±0.197 a

Means with different letter are significant differ ((P<0.05)

References

Asgharzadeh, A., B. Shabanpour, S. P. Aubourg, and H. Hosseini. 2010. Chemical changes in silver carp (Hypophthalmichthys molitrix) minced muscle during frozen storage: Effect of a previous washing process. *Grasas y aceites* 61 (1):95-101.

Aubourg, S. P. 2001. Fluorescence study of the pro-oxidant effect of free fatty acids on marine lipids. *Journal of the Science of Food and Agriculture* 81 (4):385-390.

Cerveny, J., J. D. Meyer, and P. A. Hall. 2009. Microbiological spoilage of meat and poultry products. In *Compendium of the*

 ISSN 2072-3875

microbiological spoilage of foods and beverages: Springer, 69-86.

Duncan, D. B. 1955. Multiple range and multiple F tests. *Biometrics* 11 (1):1-42.

El-Sherif, S. 2001. Chemical and technological studies on Shrimp and its wastes.

El Lahamy, A. 2020. Mohamed changes in fish quality during canning process and storage period of canned fish products: Review article. *Glob. J. Nutr. Food Sci* 3:1-7.

Enser, M., N. Scollan, S. Gulati, I. Richardson, G. Nute, and J. Wood. 2001. The effects of ruminally-protected dietary lipid on the lipid composition and quality of beef muscle. Paper read at INTERNATIONAL CONGRESS OF MEAT SCIENCE AND TECHNOLOGY.

García-Arias, M., M. Navarro, and M. García-Linares. 2004. Effects of different thermal treatments and storage on the proximate composition and protein quality in canned tuna. *Archivos latinoamericanos de nutricion* 54 (1):112-117.

Hedrick, H. B. 1994. *Principles of meat science*: Kendall/Hunt Publishing Company.

ICOSQC;. 1987. ICOSQC; Iraqi Central Organization for Standardization and quality control

Kanner, J. 1994. Oxidative processes in meat and meat products: quality implications. *Meat science* 36 (1-2):169-189.

Mackie, I. 1993. The effects of freezing on flesh proteins. *Food Reviews International* 9 (4):575-610.

Maheswara, K., C. Raju, J. Naik, R. Prabhu, and K. Panda. 2011. Studies on thermal processing of tuna-a comparative Study in tin and tin-free steel cans. *African Journal of Food, Agriculture, Nutrition and Development* 11 (7):5539-5560.

Mawlood, M. H., and Z. K. Khidhir. 2018. MICROBIOLOGICAL ASSESSMENT OF CHICKEN BREAST MEAT FROM UNLICENSED AND LICENSED SLAUGHTERHOUSES DURING REFRIGERATION AND FREEZING STORAGE. *Basrah Journal of Veterinary Research* 17 (3).

Nychas, G.-J. E., P. N. Skandamis, C. C. Tassou, and K. P. Koutsoumanis. 2008. Meat spoilage during distribution. *Meat Science* 78 (1-2):77-89.

Rukchon, C., S. Trevanich, T. Jinkarn, and P. Suppaku. 2011. Volatile compounds as quality indicators of fresh chicken and possible application in intelligent packaging. Paper read at 12th Asian Food Conference, Bangkok, Thailand.

Selmi, S., L. Monser, and S. Sadok. 2008. The influence of local canning process and storage on pelagic fish from Tunisia: fatty acid profiles and quality indicators. *Journal of food processing and preservation* 32 (3):443-457.

Simitzis, P., G. Symeon, M. Charismiadou, J. Bizelis, and S. Deligeorgis. 2010. The effects of dietary oregano oil supplementation on pig meat

 ISSN 2072-3875

characteristics. *Meat science* 84 (4):670-676.

Standard. 1998. Meat and Meat Products – Canned Luncheon Meat, .

Warren. 1998. Examination of canned foods.

Hypertext source: Bacteriological Analytical Manua.

Xia, X., B. Kong, J. Liu, X. Diao, and Q. Liu. 2012. Influence of different thawing methods on physicochemical changes and protein oxidation of porcine longissimus muscle. *LWT-Food Science and Technology* 46 (1):280-286.

XLSTAT. 2016. Addinsoft. Pro version 7.5.3 http: //WWW. Xlstat.com/en/ho.

Yoshida, H., I. Kondo, and G. Kajimoto. 1992. Participation of free fatty acids in the oxidation of purified soybean oil during microwave heating. *Journal of the American Oil Chemists' Society* 69 (11):1136-1140.

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