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Thermal diffusivities and influence of cooking time on textural, microbiological and sensory characteristics of turkey meat prepared products

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ABSTRACT

Cooking represents an important step in food processing for both sensorial and safety aspects. The aim of this study is to determine (i) the thermal diffusivity and (ii) the impact of cooking time on sensorial and microbiological characteristics of sausages (locally called salami) and ham products prepared from turkey meat. The water immersion method is used for cooking and cooling. Time–temperature profiles and thermal diffusivity values show that heat penetration in ham is slower than heat penetration in salami products. Three cooking times were applied to each material, and cooking time variation had a significant ($p < 0.05$) effect on the textural parameters of both salami and ham samples. Sensorial tests also showed significant differences ($p < 0.05$) between products cooked for different times, whereas all three gave acceptable hygienic parameters.

Keywords: Turkey meat products; Cooking; Cooling; Thermal diffusivity; Texture; Microbiology

1. Introduction

Products based on turkey meat, such as salami and ham, are popular ready-to-eat meat products in Tunisia and other North African countries. Cooking represents an important step in the preparation of meat products as the heat induced reactions affect the sensorial qualities (i.e. colour, aroma, flavour, texture) of the final product and its acceptability to the consumer. The cooking system, methodology and conditions are chosen to achieve the desired qualitative properties. When cooking is performed in hot water baths there is an optimal time and temperature for progressing desired chemical reactions (protein denaturation, starch gelatinisation, Maillard reactions), physical characteristics and limiting undesired ones (Lund, 2003). In addition to sensorial properties, thermal treatment modifies the microbial status and thereby improves the safety of these products via the effects of heat on spoilage and/or poisoning micro-organisms. Process optimisation can also reduce the energy cost of these operations. The choice of cooking process parameters must therefore represent an acceptable compromise between sensory quality, microbiological safety and energy use. Thus the optimisation of cooking and cooling conditions of meat products is of interest. To control and optimise cooking operations, fundamental physical processes and physical properties should be analysed and estimated.

Several scientific studies were devoted to cooking process of different meat products (pork, beef ...). Markowski et al. (2004) focused in their studies on the determination of thermal diffusivity of Lyoner type sausages during water bath cooking and cooling. Pittia et al. (2008) used *F*-value comparisons to optimise cooking of different food dishes such as minced beef meat roast and beef meat filled peppers in a semi-automatic oven. Siripon et al. (2007) focused their studies on heat transfer modelling of chicken cooked in hot water. Torley et al. (2000) studied the influence of environmental conditions and cooking temperature on functional properties of normal and pale, soft, exudative (PSE) pork. Few data are available, however, on the influence of cooking process parameters on qualities of formulated products based on chicken and turkey meat.

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Nomenclature

$J0$	Bessel functions of the first kind and of zero order
$J1$	Bessel functions of the first kind and of first order
L	half length of a cylinder (m)
m	number of samplings during temperature measurements
n	unit vector normal to the external surface of the sample
r	radial coordinate (m)
R	radius of a cylinder (m)
T	temperature (°C)
t	time (s)
z	axial coordinate (m)

Greek letters

α	thermal diffusivity ($m^2\ s^{-1}$)
β	thermal expansion (K^{-1})

Subscripts

0	initial
c	sample centre
S	sample external surface
W	water

In this work the first part is devoted to estimate the thermal diffusivity of formulated turkey meat products subjected to cooking followed by cooling in a water immersion bath. The second part reports the influence of cooking time on sensorial, textural and microbiological characteristics of these products.

2. Materials and methods

2.1. Sample preparation

The raw material used was fresh turkey meat, mechanically separated turkey (MST) and skin emulsion (fat), all obtained from local processors (Chahia, Sfax Tunisie). Food-grade commercial preparations of carraghenane and modified starch (E1422) (Sigma Chemical Co., St. Louis, MO) and analytical grade NaCl, $NaNO_2$, ascorbic acid and sodium tripolyphosphate (TPP) were used. Cold distilled water was used in all formulations (4 °C).

In general, the term "salami" is reserved to dried and fermented meat products by starter cultures or by natural process. In Tunisia and other North African countries, the term "salami" was attributed to cooked meat emulsion. In this study the term "salami" was used for different meat products.

Three salami and one ham formulations were prepared: (i) standard salami (SD), (ii) salami with olive (SO), (iii) salami with pepper sauces: "«hrousse» sauces" (Tunisian salami: ST) and turkey ham (TH). All these products are commercial items with extensive consumption in Tunisia and other North African countries.

For standard salami, salami with olive and Tunisian salami, MST was used. Ham however, was produced using fresh turkey meat. All salami samples contain 1.6% $NaNO_2$ and 0.5% TPP. The formulations of the salami samples are presented in Table 1. For ham samples the formula was 75% fresh turkey meat and 25% aqueous solution containing TPP, ascorbic acid, modified starch, aroma, salt and carraghenane.

Turkey meat (fresh or MST) was ground with a commercial food processor (Universo, Rowenta, Germany) equipped with a 14 cm blade for 10 min at the highest speed. Dry ingredients were added slowly (as powders) to the ground turkey meat while processing. Cold water was incorporated afterwards, followed by ground fat (at room temperature). The addition of ingredients took less than 5 min and the final temperature of the batters varied between 10 and 12 °C. The batters were stuffed into collagen reconstituted casing (60 mm diameter) and clipped at both ends to form lengths of 200 mm approximately. Salami and ham samples were then stored at 4 °C for future cooking operations.

2.2. Cooking and cooling procedure

Cooking processing operations were carried out using a temperature controlled water bath (Haake L, Haake Buchler Instruments, Karlsruhe, Germany). J-type thermocouples were used to determine the time–temperature history of samples during cooking and cooling. One thermocouple was placed in the bath water to measure the process temperature. The second thermocouple was fixed at the geometric centre of the sample. The third one was placed just under the sample surface, at a maximum depth of 0.5 mm. At the beginning of the experiment, the sample was placed in the water bath, with the temperature controlled within ±1 °C of the set point (90 °C). The water in the unit was not stirred during cooking or cooling. When the temperature at the centre of the sample had increased to the desired value the sample was removed from the hot water and immediately immersed in a mixture of cold water and ice, until the centre temperature decreased to ~30 °C. Temperature changes in the water bath, T_W, sample centre, T_C and on the sample surface, T_S, were monitored every 2 min. The same volume of water was used for heating and cooling, at 6× the volume of the sample. The experimental design used in this study is shown in Fig. 1.

2.3. Chemical analysis of tested samples

Moisture and ash contents were determined in representative samples according to the method prescribed by the Association of Official Analytical Chemists methods (AOAC, 2000). Protein content was estimated by Kjeldhal methods using a conversion coefficient of 6.25. Total fat content was evaluated by the Soxhlet method using petroleum–ether as extraction solvent (AOAC, 1997).

Table 1 – Formulation (wt%) of "salami" samples.

Samples	Water	Fresh meat	MST	Fat	Modified starch	Spices and vegetable ingredients	Peppers sauces (hrousse)	Olives
Standard salami (SD)	29	0	60	0	8	1	0	0
Salami with olives (SO)	25	5	50	0	6	3	0	9
Tunisian salami (ST)	23	5	55	5	4	4	2	0

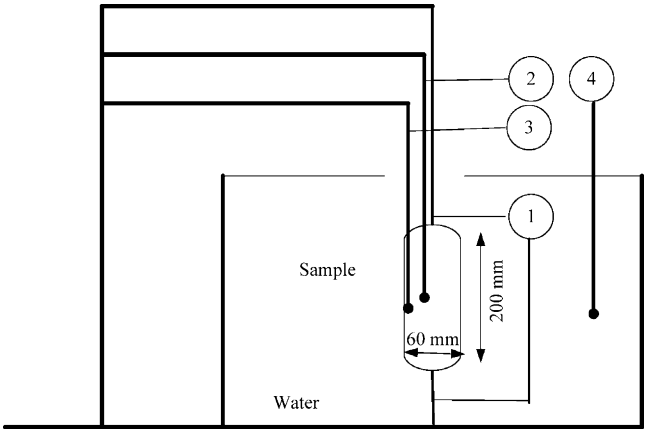

Fig. 1 – Apparatus for the cooking and the cooling of salami and ham samples in a water bath (showing orientation of the sample and the placements of the thermocouple tips). (1): located strings, (2): temperature at the sample centre (Tc), (3): temperature at the sample surface (Ts), (4): temperature of the water bath (Tw).

2.4. *Thermal diffusivity determination*

To simplify the problem, the sample was modelled as a finite cylinder with radius R and length 2L. The method used is based on the analytical solution of the conduction heat transfer equation written in cylindrical co-ordinates. This method was described and applied by Tavman et al. (1997) to measure the thermal diffusivity of wheat and durum wheat, and a modified version was employed by Carciofi et al. (2002) to calculate the thermal diffusivity of mortadella. Markowski et al. (2004) used this experimental method and a numerical model to estimate the thermal diffusivity of Lyoner type sausages during water bath cooking and cooling. The method assumes a constant sample surface temperature T_S, and constant thermal diffusivity. If the initial temperature distribution T_0 is uniform, the exact solution of the conduction heat transfer equation written in cylindrical co-ordinates is described by Eq. (1) (Carslaw and Jaeger, 1959).

$$\frac{T_S - T}{T_S - T_0} = \sum_{m=1}^{\infty}\sum_{n=1}^{\infty} \frac{2(-1)^{m+1}}{\beta_m} \cos\left(\frac{\beta_m z}{L}\right) \frac{2J_0(\beta_n r/R)}{\beta_n J_1(\beta_n)} \times \exp\left[-\left(\frac{\beta_n^2}{R^2} + \frac{\beta_m^2}{L^2}\right)\alpha t\right] \quad (1)$$

If the sample is exposed to the temperature difference for a long time, Eq. (1) can be reduced to the first term of the series. For $m = n = 1$, $\beta_m = \pi/2$, $\beta_n = 2{:}405$, $J_1\ (2{:}405) = 0{:}519$, and at the centre of a cylindrical sample $z = 0$, $r = 0$ and $J_0\ (0) = 1{:}0$. The temperature change at the central point of the sample in the case of long exposure to external temperatures is then given by

$$Ln|T_S - T_C| = Ln(2.0396|T_S - T_0|) - \left[\left(\frac{2.405}{R}\right)^2 + \left(\frac{2 \times \pi}{L}\right)^2\right]\alpha t \quad (2)$$

Eq. (2) is linearly time-dependent and can be transformed to the equivalent linear form (Eq. (3)) with slope B and intercept A.

$$Ln|T_S - T_C| = A - Bt \quad (3)$$

The thermal diffusivity then can be calculated from

$$\alpha = B\left[\left(\frac{2.405}{R}\right)^2 + \left(\frac{2 \times \pi}{L}\right)^2\right]^{-1} \quad (4)$$

B can be calculated from experimental data using linear regression. The temperature of the water bath during cooking and cooling was assumed to be constant.

2.5. *Influence of cooking time on textural, microbiological and sensory characteristics*

2.5.1. *Cooking procedure*

For all cooking operations water temperature was maintained at 90 °C. For this type of product, FDA-CFSAN (2003) recommends to stop cooking processing when a final internal temperature of 74 °C is reached. This recommendation cannot be applied to all the products because the initial microbial charge and desired physico-chemical changes from one formulation to another. To study the impact of cooking time on hygienic and organoleptic characteristics of tested samples, the following procedure is followed.

For each product, a complete thermal profile is determined and the time required to reach the temperature of 70 °C estimated. On the basis of this time and according to the industrial procedure, a range of three cooking times was applied. Operating conditions as well as fixed times of cooking are summarized on Table 2. Cooked samples at a different time are analysed for their texture, microbiological and organoleptic characteristics.

2.5.2. *Textural analysis*

All samples subject to textural procedure testing had been stored for 24 h at 4 °C. Hardness (force required to deform a product to a given distance), cohesiveness (gel capacity to maintain intact the network structure), elasticity (ratio to which a deformed sample returns to its initial position) and chewiness (necessary force to separate the product from specific surface) values were measured as described by Ayadi et al. (in press). Two measurements were made for each replicate

Table 2 – Selected cooking times and measured sample centre temperatures.

Samples	Selected time (min)	Sample centre temperature (°C)
Standard salami (SD)	37	70.2
	41	74.6
	45	77.6
Salami with olives (SO)	34	70.1
	40	75.8
	45	80
Tunisian salami (ST)	29	70.3
	37	79
	45	83.4
Turkey ham (TH)	37	70.5
	41	71.2
	45	76.3

Table 3 – Chemical composition of tested turkey meat products.

Samples	Dry matter (%)	Proteins (%DM)	Fat (%DM)	Ash (%DM)
Standard salami (SD)	33.99[a]	12.65[a]	20.73[a]	10.08[a]
Tunisian salami (ST)	39.55[b]	10.19[a]	29.64[b]	10.08[a]
Salami with olives (SO)	42.26[c]	8.62[b]	39.58[c]	9.12[a]
Turkey ham (TH)	30.49[d]	22.96[c]	2.80[d]	13.62[b]

Different letters in the same column indicate significant differences ($p < 0.05$).

and mean values are reported. Texture profile analysis (TPA) of salami and ham samples was performed. Sample discs 2 cm thick and 2 cm in diameter were cut from the centre of the cylindrical samples and compressed twice to 50% of their original height between flat plates and a cylindrical probe (1 cm^2 in diameter). A texturometer (LLOYD instruments, England) was used to perform textural measurements.

2.5.3. *Microbial analysis*

Bacterial counts were determined before and after cooking operations. The initial broth was made by aseptic blending 10 g of sample with 90 ml 1 g/l peptone solution in a stomacher (Moulinex, spain) for 60 s. Appropriate serial dilutions were plated in duplicate with Plate Count Agar (PCA, pronadisa) for total mesophilic aerobic count (incubated at 37 °C for 2 days). Total coliform count (incubated at 37 °C for 2 days), with DLC Agar (Gélose de lactose et désoxydation, pronadisa, 45 g/l). TSN Agar (pronadisa, 40 g/l) was used for anaerobic sulfite reducing (incubated at 46 °C for 2 days) counting. *S. aureus* were counted using CHAPMAN Agar after incubation at 37 °C for 3 days.

2.5.4. *Sensory analysis*

Sensory analyses were conducted by 10 panellists, who were experienced in sensory evaluation of foods, but received no specific training relevant to these products. Panellists were asked to indicate how much they liked or disliked each product on a 4-point hedonic scale (4, like extremely; 1, dislike extremely). They scored the overall acceptability of the products, according to taste, flavour, texture and colour characteristics. 2 cm long pieces were distributed in white polystyrene plates and presented to the panellist with three-digit codes and in random order for evaluation. A tap water rinse was supplied to panellists between samples. Experiments were conducted in an appropriate designed room and a global score was calculated for each product.

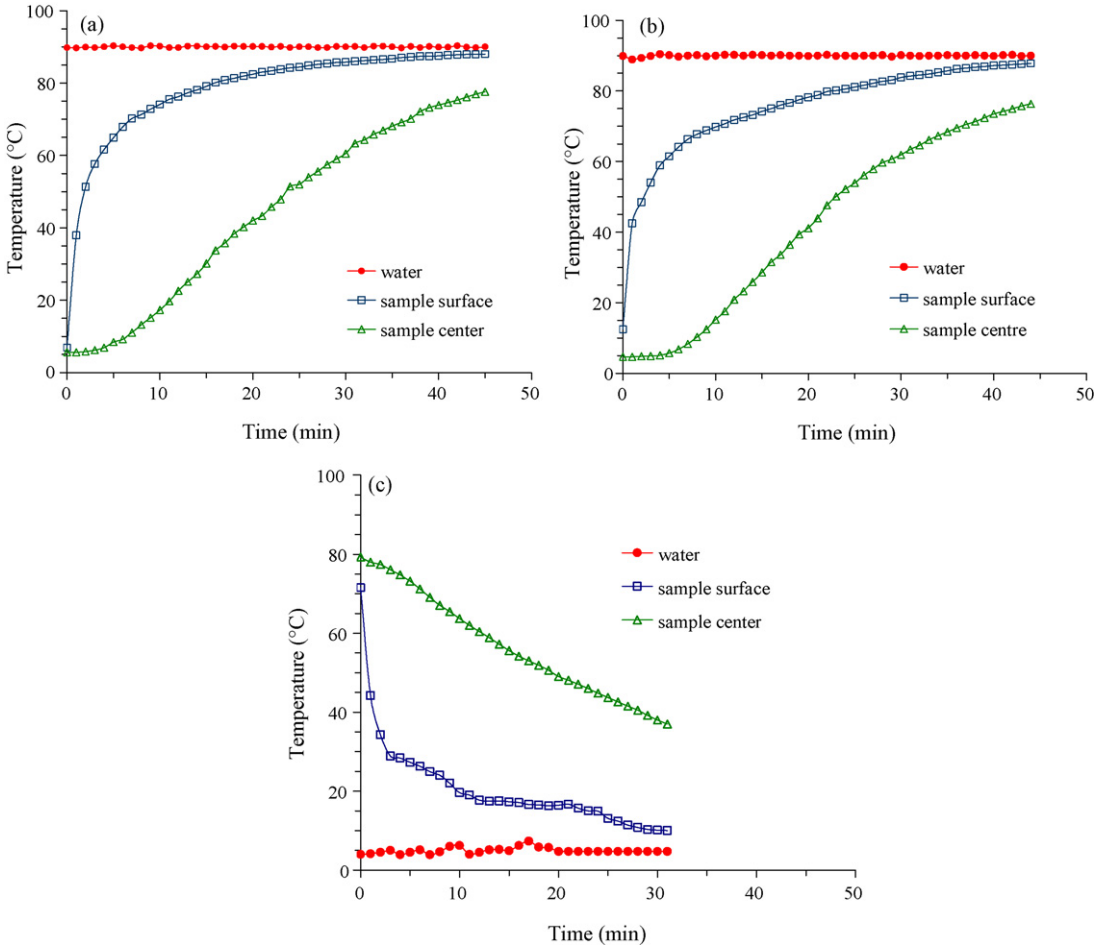

Fig. 2 – Time–temperature profiles obtained during cooking and cooling of salami and ham samples. (a) Cooking of standard salami (SD), (b) cooking of Turkey ham (TH) and (c) cooling of standard salami (SD).

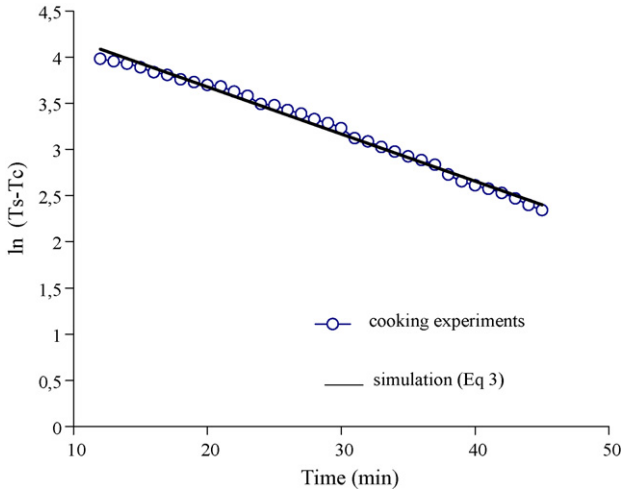

Fig. 3 – Typical experimental and simulated time–temperature evolution at the centre of a sample during cooking.

2.6. *Statistical analysis*

Analyses and sample treatments were repeated at least three times. Means and standard deviations were calculated and SPSS for Windows software (version 13.0, SPSS Inc., IL, Chicago, USA) was used to verify significant differences between treatments and means by Turkey's test at $p < 0.05$.

3. Results and discussion

3.1. *Chemical analysis*

The results of proximate analyses of tested samples are shown in Table 3. Dry matter varies between 30.49 and 42.26 wt%. This difference can be explained by the amount of water added during preparation and the nature of raw material (MST or fresh meat) for each product. Table also shows a large variation of fat content and protein levels between salami products (SD, TS and SO) and ham. Indeed, turkey ham is richer in protein than the various types of salami, while salami with olives has the highest fat content. The variation in protein and fat content between ham and salami can be attributed to meat type: ham is produced using fresh turkey meat and salami samples are prepared using mechanically separated turkey (MST) which contains less proteins and more fat than fresh turkey meat. The high fat content in SO samples is due to the addition of olives.

Although MST is richer in minerals than fresh meat, the ash content in the ham sample is higher than in salami ones. This difference is due primarily to the addition of compounds such as nitric salt and polyphosphates during ham formulation.

3.2. *Time–temperature profiles and thermal diffusivity estimation*

Fig. 2 presents typical time–temperature patterns. Heat penetration in the salami sample is faster, which is consistent with the differences in composition and structure: uncooked salami products are a fine meat emulsion, whereas ham is a mixture of an aqueous solution, meat particles and additives.

Fig. 3 shows a typical temperature profiles over time (on a semi-log plot scale). In their study of mortadella cooking, Carciofi et al. (2002) observed two periods, with different slopes. Such behaviour was not observed in the present study. In all cases, the plots of Eq. (3) show a curvilinear part in the beginning of the process, followed by one linear region, as reported by Markowski et al. (2004).

Table 4 – Estimated thermal diffusivities values for cooking and cooling of salami and ham.

Samples	Thermal diffusivities (α) ($m^2\,s^{-1}$)	
	Cooking	Cooling
Standard salami (SD)	5.11×10^{-6}	2.30×10^{-6}
Tunisian salami (ST)	7.02×10^{-6}	5.01×10^{-6}
Salami with olives (SO)	6.02×10^{-6}	4.11×10^{-6}
Turkey ham (TH)	1.98×10^{-8}	4.41×10^{-8}

Estimated thermal diffusivities of salami and ham samples during cooking and cooling are presented in Table 4. The values for cooking are comparable to those obtained during cooling. The thermal diffusivities for the three salami types are about $10^{-6}\,m^2\,s^{-1}$, whereas that of turkey ham is about $10^{-8}\,m^2\,s^{-1}$.

Several studies have reported estimates thermal diffusivity, α, of beef and pork meat prepared products during cooking and cooling processes. However few data are available in the literature from turkey and chicken meat products. Dickenson and Read (1975) and Kong et al. (1994) reported that the thermal diffusivity of lean beef varied from $0.4 \times 10^{-7}\,m^2\,s^{-1}$ at 30 °C to $1.3 \times 10^{-7}\,m^2\,s^{-1}$ at 66 °C. Thus, as reported by Singh (1982), we can expect a variable thermal diffusivity value during a given cooking and cooling process. Markowski et al. (2004) estimated thermal diffusivities of products prepared from beef and pork using analytical and numerical methods. They reported a significant difference between α values obtained from analytical methods and values obtained using the numerical one. They reported thermal diffusivity values obtained using analytical methods between about 3.5×10^{-7} and about $4.5 \times 10^{-7}\,m^2\,s^{-1}$. Sheridian and Shilton (2002) studied the influence of cooking and fat contents on α of ground beef patties using infrared radiation technology, and reported that α varied over the progress of cooking and fat content and varied between 1.22×10^{-7} and $1.82 \times 10^{-7}\,m^2\,s^{-1}$. Indeed, Sheridian and Shilton (2002) reported that increasing the fat level in ground beef patties increased heat penetration in the sample. Bacikava and Klein (1979) reported an approximate α value of fat as $1.1 \times 10^{-7}\,m^2\,s^{-1}$. The thermal diffusivities values obtained here differ from these published values, which for beef and pork prepared products are about $10^{-7}\,m^2\,s^{-1}$, salami $10^{-6}\,m^2\,s^{-1}$ and ham $10^{-8}\,m^2\,s^{-1}$. These observed differences could be explained by the structure of each sample and the raw material used for formulation.

3.3. *Influence of cooking time on textural, microbiological and sensory characteristics*

3.3.1. *Textural change*

The development of textural, microbiological and organoleptic characteristics depends on cooking time. Based on the thermal profiles, three cooking times were applied and the influence of this cooking time on sensory, microbiological and textural characteristics was studied.

Table 5 summarizes the measured textural changes in salami and ham samples cooked at various times. Our results show that cooking time has a significant ($p < 0.05$) effect on textural parameters of Turkey salami and ham. Hardness values show that increasing cooking time leads to an increase

Table 5 – Textural profile analysis (TPA) of salami and ham samples.

Samples	Cooking time (min)	Hardness (N)	Cohesiveness	Elasticity	Chewiness (N mm)
Standard salami (SD)	37	13.35[a]	0.39[a]	8.64[a]	46.05[a]
	41	17.47[b]	0.36[a]	8.80[a]	59.19[b]
	45	22.49[c]	0.38[a]	9.23[b]	68.21[c]
Tunisian salami (ST)	34	30.22[a]	0.41[a]	8.20[a]	110.2[a]
	40	30.04[a]	0.37[b]	8.83[b]	109.0[a]
	45	23.25[b]	0.39[ab]	9.11[c]	72.32[b]
Salami with olives (SO)	29	19.12[a]	0.40[a]	10.0[a]	78.65[a]
	37	19.60[a]	0.36[b]	8.35[b]	59.78[b]
	45	24.83[b]	0.28[c]	7.77[c]	55.39[b]
Turkey ham (TH)	37	18.32[a]	0.23[a]	6.45[a]	82.622[a]
	41	25.14[b]	0.28[b]	7.41[b]	78.65[b]
	45	28.10[c]	0.37[c]	8.57[c]	57.19[c]

Different letters for each sample indicate statistically significant differences ($p < 0.05$).

in hardness, except for ST. The values presented in Table 5 show an overall decrease of chewiness versus cooking time for ST, SO and TH samples. However the chewiness values of SD increase with cooking. Increasing cooking time results in an increase of SD and ST elasticity but a decrease in SO and TH elasticity. The cohesiveness values vary slightly with cooking time for all samples.

There are several factors that can influence the texture of the studied turkey meat products. One of the first aspects to consider is protein content and origin (meat proteins and not meat proteins) which is related to the addition for example of olive in SO and "«hrousse» sauce" in ST. Non-meat ingredients are commonly used in processed meats to improve textural properties (Sze-Tao and Shate, 2000). The effect of this non-meat ingredient will depend to a large extent on how it interacts with muscle protein. Vegetable proteins of this kind generally require slightly higher temperatures (95 °C) than the temperatures applied in this study to unfold muscle proteins (Feng and Xiong, 2002). The behaviour of non-meat proteins therefore, encourages the formation of molecular associations implicated in protein gel network formation, thus producing harder textures. A second aspect to consider is the differences in fat/moisture and protein/moisture ratios. When non-meat ingredients are added, moisture, protein and fat content can vary significantly ($p < 0.05$) (Table 3). Some authors have reported that these changes produce an "effective" concentration of the muscle protein available for gel formation and are thus related to harder structures (Claus et al., 1990).

3.3.2. *Sensorial change*

Table 6 shows the global scores obtained for each material cooked for three different times. The changes caused by increasing cooking time of turkey salami and ham were significant ($p < 0.05$) as perceived by judges (Table 6). This perception was more evident for the first cooking time for all products studied. All early samples (37 min for SD, 34 min for ST, 29 min for SO and 37 min for TH) proved less acceptable to the panellists. The panel found slight differences between products cooked for longer times. Table 6 shows that increasing cooking time for SD samples increases overall acceptability. However, ST, SO and TH samples cooked for 45 min were less acceptable than samples cooked at 40, 37 and 41 min, respectively. This change of acceptability could be explained by the influence of over heating phenomena on textural (hardness, elasticity and chewiness) and organoleptical (taste, colour, odour) characteristics.

3.3.3. *Microbiological change*

Although the main objective here was to measure the influence of cooking time by water immersion on textural and organoleptical characteristics, an estimate of influence on microbiological characteristics of these foods is also desirable. Therefore, dilutions of ST and SO samples are analysed for total mesophile, faecal coliforms, *staphylococcus aureus* and anaerobia sulphide reducing count before and after cooking at different times. The choice of ST and SO samples is related to the initial bacterial flora. Indeed, these two products are manipulated more and contain more ingredients with poorer hygienic quality ("hrousse" and olives purchased from local market) than SD and TH samples. Table 7 presents bacterial counts of ST and SO samples before and after cooking at different times. Value obtained before cooking (fresh samples) shows a large and varied microbiological contamination of both samples. It is important to emphasize that SO samples are more contaminated by total flora, faecal coliforms and s. *aureus* than ST ones. On the other hand, the anaerobia sulphide reducing count is higher for ST. This difference could be explained by the large contamination of the ingredient "hrousse" for ST samples and by greater human contact to stone the olives during preparation of SO.

Table 7 also shows that after the first cooking time (34 min for ST and 29 min for SO), a significant reduction ($p < 0.05$) of

Table 6 – Sensory analysis of salami and ham samples (SD: standard salami. TS: Tunisian salami. SO: salami with olives. TH: turkey meat ham).

Samples	Cooking time (min)	Score (%)
SD	37	35[a]
	41	50[b]
	45	55[b]
ST	34	34[a]
	40	50[b]
	45	40[c]
SO	29	40[a]
	37	50[b]
	45	35[c]
TH	37	30[a]
	41	50[b]
	45	45[c]

Different letters for each sample indicate significant differences ($p < 0.05$).

Table 7 – Microbiological analysis of Tunisian salami (ST) and salami with olives (SO) samples before and after different cooking time. Results are the mean of three analyses and expressed as CFU/g.

Samples	Cooking time (min)	Total mesophile	Faecal coliforms	*Staphylococcus aureus*	Anaerobia sulfite reducing
Tunisian salami (ST)	0	$4\,10^5$	310	100	80
	34	$5\,10^4$	<10	<100	<10
	41	$2.5\,10^3$	<10	<100	<10
	45	$1.5\,10^3$	<10	<100	<10
Salami with olives (SO)	0	$6.4\,10^5$	910	200	<10
	29	$5.6\,10^4$	<10	<100	<10
	37	$3.2\,10^3$	<10	<100	<10
	45	$1.5\,10^2$	<10	<100	<10
Value recommended by Tunisian legislation (1979)		$<3 \times 10^5$	<10	$<10^2$	<30

faecal coliforms, *s. aureus* and anaerobia sulphide reducing is observed in both samples. In addition, after first cooking the faecal coliforms, *s. aureus* and anaerobia sulphide reducing counts are lower than the values recommended by Tunisian legislation. However, the first cooking times are not sufficient to meet the total mesophile count recommended in Tunisian legislation.

4. Conclusions

Measured time–temperature profiles and estimated thermal diffusivity values during cooking and cooling show that heat penetration in ham is lower than in salami ones. This heat penetration variation is attributed to raw material and formulation differences. Increasing cooking time leads to a great change in textural and sensorial characteristics of ham and salami products. Indeed, over heating can lead to hardness, elasticity and chewiness increase or decrease depending on material composition. Microbiological study shows that heating ST and SO for respectively 41 and 37 min can guarantee acceptable hygienic products comparing to Tunisian legislation.

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