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Stress Relaxation Characteristics of Chicken Sausages Containing Spent Hen Meat under Different Cooking Conditions

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Abstract

Most laying hens become unproductive after 1.5 years of age. These spent hens are normally sold at a low price because their meat is tough and therefore considered of low quality. The development of chicken sausages containing partly spent hen meat was undertaken to fulfill the purpose of adding value to the meat. Sausage samples containing 0%, 30%, 60%, and 85% by weight spent hen meat were used. The samples were cooked either by deep fat frying or microwave heating. The frying conditions were at 120°C for 60 s, 120°C for 90 s, 140°C for 60 s, and 140°C for 90 s. The microwave heating conditions were at 30% heating power for 15 s, 30% heating power for 30 s, 50% heating power for 15 s, and 50% heating power for 30 s. Calculation of viscoelastic properties by means of stress relaxation were performed. The samples were compressed by a flat probe in a material testing machine with a speed of 0.1 mm/s for 30 min with 30% strain compression. The stress relaxation behaviors were well fitted with the 2-element Maxwell model. Linear transformations of the data were also conducted. The results showed that the cooking methods and cooking temperatures had some effects on the linear parameter k_2 values. The values tended to decrease with an increase in cooking temperature. High cooking temperatures increased the solubility of collagen in broiler and spent hen meat, and consequently enhanced tenderization of the sausage mea

Keywords: spent hen, chicken sausage, viscoelastic, stress relaxation

1 Introduction

Commercial egg production in Thailand has grown extensively in the last 10 years. Most laying hens become unproductive after 1.5 years of age. However, the high rate of egg production is within a period of 70-80 weeks of their life span. After that, they are normally culled from their flocks due to their low rate of production and classified as "spent hens" (Sorapukdee et al., 2016). Because spent hen meat is tough, it provides low organoleptic quality. Therefore, they are sold at a low price. The spent hen meat is actually nutritious, a good protein source, enriched with omega-3 fatty acid, and has low cholesterol content (Ajuyah et al., 1992). The meat toughness is due to an increase of cross-linking in the connective tissue (Sorapukdee et al. 2016) and high cross-linking collagen content (Chuaynukool et al., 2007; Wongwiwat et al., 2009) with increased age.

To enhance the price of spent hen meat, value-added products from the meat have been created using it either as a main ingredient or as a substitution. Examples of the products are sausage (Ilayabharathi et al., 2012; Lengkey, 2016), jerky (Silva et al., 2017; Sorapukdee et al., 2016;), soup (Chuaynukool et al., 2007), and surimi (Jin et al., 2017; Nowsad et al., 2000; Jin et al., 2011). However, utilization occurs more often in comminuted foods, especially emulsified sausages, since toughness is no obstacle for these kinds of products.

Viscoelastic properties are texture characteristics that are normally used to explain emulsion-type food systems (Dzadz et al., 2015). These food systems are a combination of solids and fluids. Elasticity is the property of ideal or Hookean solid materials; viscosity is the property of ideal or Newtonian fluid materials. Stress relaxation testing is a fundamental mechanical means of testing viscoelastic behaviors of a food product. During testing, the product is subjected to a constant strain, and the stress required to maintain its deformation is measured as a function of time (Steffe, 1996).

The objective of this study was to characterize the stress relaxation behavior of chicken sausages containing spent hen meat under different cooking conditions: deep frying, and microwave heating

2 Materials and Methods

2.1 Sausage manufacture

Chicken sausages were made of 90% chicken meat, 5% pork fat, and 5% spices. Fresh chicken meat, some granular ice, pork fat, and spices were ground with a commercial food processor. Then, the

2018

meat paste was stuffed in artificial sausage casings, with 19.05 mm diameter and 10 cm length. The raw sausages were heated in an oven at 70°C for 30 min, and heated further in a water bath at 80°C for 15 min. The precooked sausages were then cooled immediately in ice water until reaching 4°C. Subsequently, the casings were removed and the sausages were stored in a refrigerator at 4°C for 24 hours.

Four formulations of chicken sausages with varied amounts of spent hen meat (w/w) were manufactured: 0% spent hen meat or 100% broiler meat (0% SH), 30% spent hen meat (30% SH), 60% spent hen meat (60% SH), and 85% spent hen meat (85% SH).

2.2 Cooking conditions

The sausages were cooked using 2 methods: deep frying and microwave heating. The deep frying conditions were at 120°C for 60 s, 120°C for 90 s, 140°C for 60 s, and 140°C for 90 s, using an electric deep fryer with palm oil. The microwave heating conditions were at 30% heating power for 15 s, 30% heating power for 30 s, 50% heating power for 15 s, and 50% heating power for 30 s, using a commercial microwave oven with 1,400 W of heating power.

2.3 Stress relaxation test and analysis

The samples of cooked sausages were prepared by cutting the middle section of the sausages to 35 mm in length. The average diameter of the samples was 20 mm. The stress relaxation tests were performed on each sample using a Lloyd Universal Testing Machine (Model LR5K, UK). The sample was compressed by a flat plate to 30% strain (ε_o) at a crosshead speed of 0.1 mm s^{-1}, and held for 30 min. The force as a function of was recorded.

The force was converted to stress using Eq. 1 (Steffe, 1996):

$$\sigma = \frac{F}{A} \qquad (1)$$

where σ is the stress at time t, F is the force at time t, and A is the cross-sectional area of the sample.

The data of stress as a function of time were fitted with a generalized Maxwell model (Two Maxwell elements, and one free spring in parallel) that can be represented conceptually in Fig. 1. Springs represent Hookean solids and dashpots represent Newtonian fluids. The mathematical model can be represented as in Eq. 2 (Steffe, 1996):

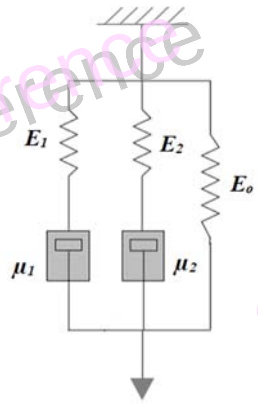

Figure 1 Conceptual diagram of Generalized Maxwell model (E_o, E_1 = elastic moduli; μ_1 = Newtonian viscosity).

$$\sigma = \sigma_e + A_1 e^{\frac{-t}{\lambda_1}} + A_2 e^{\frac{-t}{\lambda_2}} \qquad (2)$$

where σ_e is the residual stress ($\sigma_e = \varepsilon_o E_o$), A_1 and A_2 are relaxation modulus functions, t is time, and λ_1 and λ_2 are relaxation times ($\lambda_1 = \frac{\mu_1}{E_1}$, $\lambda_2 = \frac{\mu_2}{E_2}$).

To overcome the difficulty of mechanical parameter determination at the equilibrium state, the stress and time data were also transformed to fit a linear model in Eq. 3 (Steffe, 1996):

$$\frac{\sigma_o t}{\sigma_o - \sigma} = k_1 + k_2 t \qquad (3)$$

where σ_o is the initial stress and k_1 and k_2 are constants. The reciprocal of k_1 depicts the initial decay rate, and k_2 is a hypothetical value of the asymptotic normalized force. Peleg and Normand (1983) explained that k_2 is associated with the solid property of a material. Its values range from 1 (ideal liquid materials) to ∞ (ideal solid materials).

2.4 Statistical analysis

Analysis of variance and pairwise comparisons of relaxation time values and k_2 values were computed using Minitab 18.1 software (Minitab, Inc., State College, PA).

3 Results and Discussion

Examples of the stress relaxation curve of the chicken sausages were shown in Fig. 2. All samples behaved similarly. During their constant deformations, the stress required to hold that constant deformation was not constant, but decaying with time. For ideal solids which possess elasticity, their stress will be constant with time; they never relax. In contrast to ideal fluids which possess viscosity, flowing causes energy dissipation, losing energy to recover; they relax instantaneously (Steffe, 1996). The stress responses of the sausages show a typical behavior of viscoelastic materials, falling in between solid and fluid regimes. Viscoelastic properties are important factors associated with the texture characteristics of sausages, as seen in many studies (Andrés et al., 2008; Chen et al., 2006; Del Nobile et al., 2007; Lengkey et al., 2016). From Fig. 2, generally, in both cooking methods, the sausages containing high spent hen meat (85%) elicited higher initial stress and residual stress values than the ones without spent hen meat. This evidence confirms that the toughness of spent hen meat has some influence on the texture of food products. Some additives such as carrageenan (Lengkey et al., 2016) or glycerol (Sorapukdee et al., 2016) might be added to the products to improve organoleptic qualities.

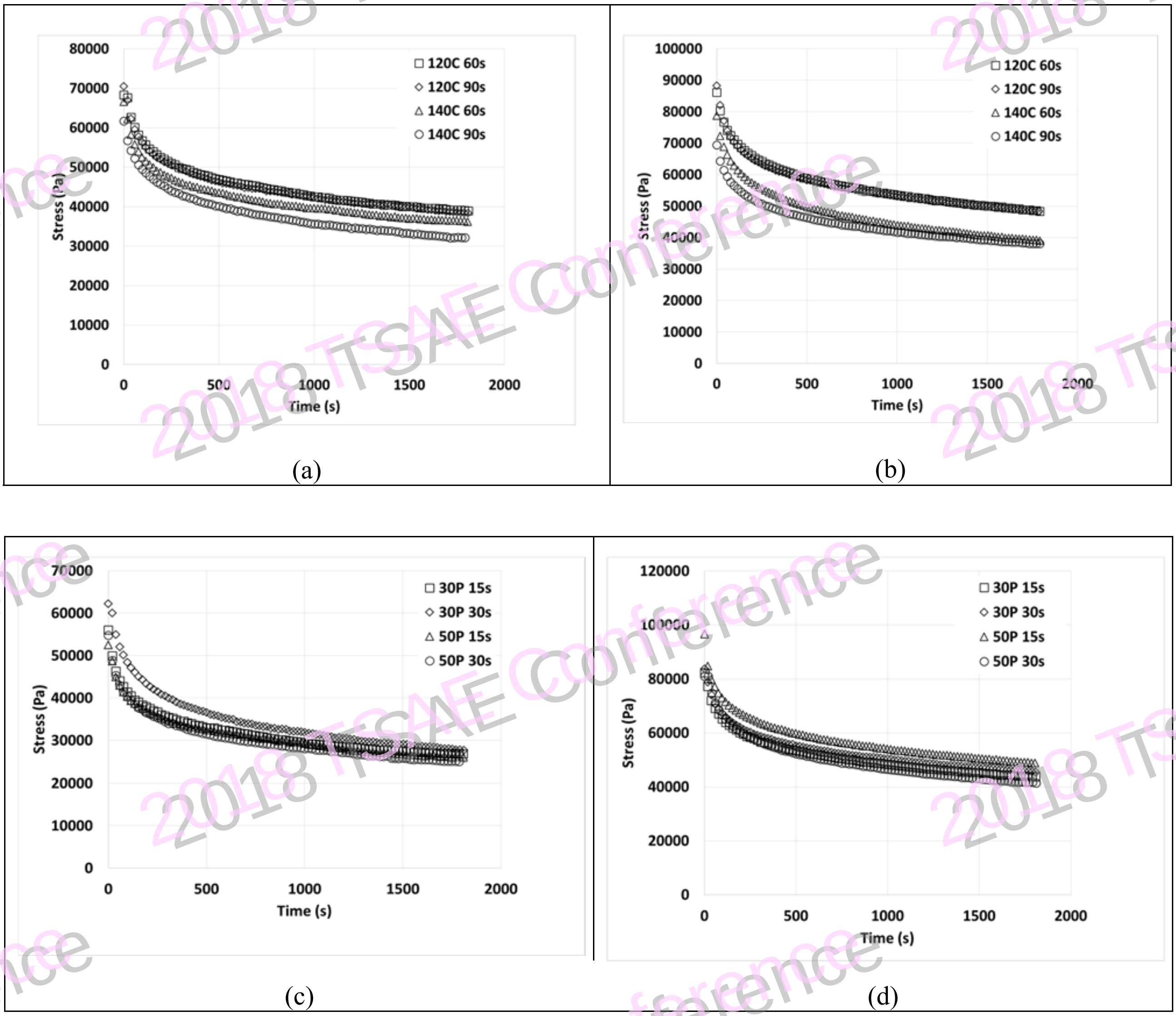

Figure 2 Stress relaxation curves of chicken sausages: (a) 0% SH deep frying, (b) 85% SH deep frying, (c) 0% SH microwave heating, and (d) 85% SH microwave heating; 30P = 30% heating power.

The stress responses as a function of time obtained from all samples were well fitted with a generalized Maxwell model, as shown in Eq. 2 ($r^2 \geq 0.95$). The parameters of the model for both cooking methods were shown in Tables 1 and 2. Good fitting with the linear model in Eq. 3 was also observed ($r^2 \geq 0.99$), and the parameters were shown in Tables 3 and 4. For the generalized Maxwell model, several parameters were obtained; however, relaxation times are the most important ones. From Tables 1 and 2, the range of values for both relaxation times fit "bulky foods" as explained by Del Nobile et al. (2007). They implied that the bulky foods are foods that have dense structures or contain less air in their pores such as in meat, agar, and ripened cheese. Thus, they elicit longer relaxation times than spongy foods like white bread and mozzarella cheese. For the statistical analyses, as mentioned earlier, due to the complexity of food materials, the interpretations of Maxwell parameters are complicated, and must be done with care. Both relaxation times of both methods did not show a significant trend at significance level of 0.05 or less. However, λ_2 values of deep frying method tended to decrease at higher cooking temperatures.

The effect of spent hen meat in the sausages was not prominent. For the microwave heating method, the sausages that contained spent hen meat tended to give higher λ_2 values than those containing 100% broiler meat. On the other hand, Tables 3 and 4 showed significant differences in k_2 values ($p \leq 0.005$) for both cooking methods. Similar trends were observed here. In the case of the deep frying method, regardless of spent hen meat ratios in the sausages, k_2 values tended to decrease with an increase in frying temperature. In the case of the microwave heating method, spent hen meat played an important role in increasing k_2 values. However, the influence of spent hen meat ratios was not obvious. Additionally, the k_2 values showed a decreasing trend at higher heating conditions. This follows the simpler explanation of Peleg and Normand (1983), that a decrease of k_2 values designates more fluid-like samples. High cooking or heating temperatures resulted in a soft texture of the sausage meat. Chuaynukool et al. (2007) found that the heating process while making Tom Yum soup could increase heat soluble muscle collagen 44% for spent hen meat. They also reported that lower heating temperature and long process time yielded higher collagen solubility than the higher heating temperatures. However, it could be hypothesized that cooking temperatures dependent on cooking methods can affect the solubility of collagen in spent hen meat. Here, the results showed that high temperature with short cooking time could increase collagen solubility of the meat, and consequently enhance tenderization of the sausage meat. The sausages cooked by microwave heating method gave lower k_2 values than those cooked by deep frying method. It is also obvious that the cooking method could be a factor affecting collagen solubility of spent hen meat and viscoelastic properties and texture characteristics of these sausages. The unique internal and rapid heating of the microwave may play an important role in collagen solubility of spent hen meat. More research studies in this area should be carried out.

Table 1 Generalized Maxwell's parameters of chicken sausages under deep frying method

Cooking condition	0% SH					30% SH				
	A_1 (Pa)	λ_1 (s)	A_2 (Pa)	λ_2 (s)	σ_e (Pa)	A_1 (Pa)	λ_1 (s)	A_2 (Pa)	λ_2 (s)	σ_e (Pa)
120 °C 60 s	16,300 ±2093	70.7 ±12.2	18,555 ±403.1	923.8^{bc} ±50.8	36,410 ±325.3	18,050 ±1,329.4	66.7 ±19.5	19,880 ±198.0	926.9^{bc} ±56.1	34,410 ±848.5
120 °C 90 s	16435 ±91.9	68.2 ±1.2	18,240 ±466.7	928.2^{bc} ±4.2	36,625 ±615.2	19,030 ±721.2	65.8 ±9.9	21,310 ±99.0	863.4^{bcde} ±84.4	43,985 ±1,096.0
140 °C 60 s	14,855 ±784.9	66.4 ±4.0	17,000 ±424.3	858.8^{bcde} ±7.1	34,130 ±240.4	17,820 ±1,004.1	76.6 ±5.6	20,540 ±735.4	956.2^{b} ±14.6	38,695 ±148.5
140 °C 90 s	15,385 ±3995.2	70.8 ±5.7	18,815 ±742.5	868.1^{bcde} ±38.2	29,375 ±1,110.2	20,165 ±1,647.6	61.4 ±18.5	22,090 ±2,361.7	940.3^{bc} ±63.8	35,690 ±4,539.6

Cooking condition	60% SH					85% SH				
	A_1 (Pa)	λ_1 (s)	A_2 (Pa)	λ_2 (s)	σ_e (Pa)	A_1 (Pa)	λ_1 (s)	A_2 (Pa)	λ_2 (s)	σ_e (Pa)
120 °C 60 s	19,090 ±1,753.6	73.2 ±0.6	20,180 ±56.6	1,340.1^{a} ±59.3	36,180 ±2,842.6	15,920 ±141.4	66.8 ±0.9	23,725 ±176.8	887.1^{bcde} ±21.1	43,935 ±2,241.5
120 °C 90 s	20,500 ±2,559.7	80.6 ±13.3	24,520 ±1,979.9	1,307^{a} ±115.3	32,605 ±2,255.7	17,420 ±2,588.0	63.6 ±3.5	22,660 ±212.1	873.6^{bcde} ±30.5	46,635 ±770.7
140 °C 60 s	15,330 ±2,375.9	66.3 ±0.5	21,785 ±1,619.3	874.3^{bcde} ±3.6	37,250 ±551.5	15,140 ±1,301.1	68.8 ±4.6	23,495 ±2,001.1	833.9^{cde} ±60.2	37,420 ±763.7
140 °C 90 s	16,815 ±2,722.4	62.9 ±0.3	22,800 ±70.7	817.7^{de} ±8.2	34,000 ±1,103.1	14,380 ±1,499.1	66.2 ±0.3	19,780 ±834.4	804.2^{e} ±15.9	36,580 ±410.1

Means ± SD of λ_2 values identified by different superscripts are significantly different ($p \leq 0$)

Table 2 Generalized Maxwell's parameters of chicken sausages under microwave heating method.

Cooking condition	0% SH					30% SH				
	A_1 (Pa)	λ_1 (s)	A_2 (Pa)	λ_2 (s)	σ_e (Pa)	A_1 (Pa)	λ_1 (s)	A_2 (Pa)	λ_2 (s)	σ_e (Pa)
30P 15s	13,770 ±989.9	49.5 ±2.8	19,125 ±5,070.0	702.4^{d} ±2.2	23,415 ±3,160.8	15,695 ±2,298.1	76.4 ±17.6	20,535 ±35.4	943.3^{a} ±111.4	37,135 ±572.8
30P 30s	14,975 ±2,821.4	74.5 ±11.1	19,690 ±396	877.5^{abcd} ±70.4	24,695 ±1,463.7	15,775 ±473.8	65.1 ±0.1	22,485 ±1,096.0	867.6^{abcd} ±19.3	43,370 ±608.1
50P 15s	12,060 ±2,375.9	63.3 ±1.8	14,610 ±933.4	920.7^{a} ±160.2	23,870 ±820.2	15,320 ±1,357.6	69 ±5.4	20,095 ±1,180.9	875.1^{abcd} ±35.1	36,615 ±417.2
50P 30s	13,955 ±742.5	57.5 ±8.1	16,045 ±530.3	739.9^{bcd} ±56.4	23,760 ±551.5	16,680 ±848.5	54.2 ±8.2	21,680 ±2,347.6	787.2^{abcd} ±7.1	29,575 ±346.5

Cooking condition	60% SH					85% SH				
	A_1 (Pa)	λ_1 (s)	A_2 (Pa)	λ_2 (s)	σ_e (Pa)	A_1 (Pa)	λ_1 (s)	A_2 (Pa)	λ_2 (s)	σ_e (Pa)
30P 15s	17,195 ±1,803.1	71.6 ±4.8	20,570 ±1,315.2	915.1^{ab} ±76.2	39,520 ±169.7	19,170 ±226.3	62.5 ±6.3	22,455 ±487.9	844.5^{abcd} ±94	41,170 ±353.6
30P 30s	13,285 ±318.2	681 ±2.0	20,055 ±982.9	890.6^{abc} ±41.3	33,730 ±226.3	18,160 ±707.1	60.5 ±11.3	22,055 ±516.2	798.7^{abcd} ±113.1	43,390 ±240.4
50P 15s	16,675 ±1,647.6	77.8 ±13.5	19,720 ±3,436.5	941.2^{a} ±79.5	38,485 ±1,958.7	20,830 ±2,262.7	63.7 ±29.7	25,250 ±608.1	827.3^{abcd} ±148.6	45,245 ±2,934.5
50P 30s	20,145 ±1,294	45.5 ±16.6	21,490 ±961.7	718.3^{cd} ±34.6	36,700 ±1,583.9	20,380 ±113.1	84.1 ±13.5	24,835 ±558.6	924.2^{a} ±74.2	39,500 ±2,432.4

Means ± SD of λ_2 values identified by different superscripts are significantly different ($p \leq 0.132$)

Table 3 Linear parameters of chicken sausages under deep frying method.

Cooking condition	0% SH		30% SH		60% SH		85% SH	
	k_1 (s)	k_2	k_1 (s)	k_2	k_1 (s)	k_2	k_1 (s)	k_2
120 °C 60 s	435.910 ±108.795	2.040^{ab} ±0.074	492.475 ±1.039	1.940^{bc} ±0.022	389.850 ±30.688	1.983^{abc} ±0.006	484.835 ±18.745	2.035^{ab} ±0.055
120 °C 90 s	414.450 ±4.469	2.035^{ab} ±0.003	410.945 ±49.236	2.046^{ab} ±0.021	420.465 ±97.899	1.799^{de} ±0.109	455.455 ±68.017	2.105^{a} ±0.077
140 °C 60 s	412.260 ±33.701	2.023^{ab} ±0.002	443.665 ±38.785	1.994^{abc} ±0.045	447.085 ±51.541	1.940^{bc} ±0.112	453.825 ±40.864	1.880^{cde} ±0.114
140 °C 90 s	395.315 ±58.216	1.928^{bcd} ±0.050	346.520 ±41.323	1.873^{cde} ±0.032	393.885 ±51.032	1.788^{e} ±0.064	428.445 ±23.879	1.980^{abc} ±0.056

Means ± SD of k_2 values identified by different superscripts are significantly different ($p \leq 0.005$)

Table 4 Linear parameters of chicken sausages under microwave heating method

Cooking condition	0% SH		30% SH		60% SH		85% SH	
	k_1 (s)	k_2	k_1 (s)	k_2	k_1 (s)	k_2	k_1 (s)	k_2
30P 15s	322.660 ±34.479	1.631^{h} ±0.205	477.190 ±20.181	2.001^{abcd} ±0.014	439.855 ±54.428	2.132^{ab} ±0.045	384.810 ±29.006	1.937^{cdef} ±0.043
30P 30s	382.310 ±23.518	1.769^{fgh} ±0.183	747.050 ±30.929	2.162^{a} ±0.082	461.800 ±35.497	2.083^{abc} ±0.133	395.290 ±28.765	2.002^{abcd} ±0.037
50P 15s	386.345 ±25.760	1.869^{defg} ±0.066	449.015 ±2.440	1.974^{abcde} ±0.037	468.290 ±9.588	1.942^{bcdef} ±0.020	358.720 ±43.713	1.924^{defg} ±0.040
50P 30s	282.965 ±13.951	1.807^{efgh} ±0.127	346.840 ±20.011	1.701^{gh} ±0.047	303.080 ±41.691	1.805^{efgh} ±0.035	441.200 ±45.792	1.849^{defg} ±0.027

Means ± SD of k_2 values identified by different superscripts are significantly different ($p \leq 0.001$)

4 Conclusion

Sausages made of spent hen meat mixed with broiler meat elicited viscoelastic behaviors. Their relaxation models were well fitted with a generalized Maxwell model with 2 Maxwell elements and a free spring in parallel. However, the simpler explanations related to their texture characteristics were obtained from the k_2 values of their linear models. High cooking temperatures increased the solubility of collagen for broiler and spent hen meat, and consequently enhanced tenderization of the sausage meat.

The unique internal and rapid heating of the microwave may play an important role in collagen solubility of spent hen meat. Thus, the cooking method should be considered as a factor affecting collagen solubility of spent hen meat and viscoelastic properties of sausages containing this kind of meat

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6 References

Andrés, S.C., Zaritzky, N.E. and Califano, A.N. 2008. Stress relaxation characteristics of low-fat chicken sausages made in Argentina. Meat Science 79, 589-594.

Ajuyah, A.O., Hardin, R.T., Cheung, K. and Sim, J.S. 1992. Yield, lipid, cholesterol and fatty acid composition of spent hen fed full-fat oil seeds and fish meal diets. J. Food Sci. 57, 338-341.

Chen, C.R., Marcotte, M. and Taherian, A. 2006. Viscoelastic properties of Wiener sausages during cooking. International Journal of Food Properties 9, 205–216.

Chuaynukool, K., Wattanachant, S. and Siripongvutikorn, S. 2007. Chemical and physical properties of raw and cooked spent hen, broiler and Thai indigenous chicken muscles in mixed herbs acidified soup (Tom Yum). Journal of Food Technology 5, 180-186.

Del Nobile, M.A., Chillo, S., Mentana, A. and Baiano, A. 2007. Use of the generalized Maxwell model for describing the stress relaxation behavior of solid-like foods. Journal of Food Engineering 78, 978-983.

Dzadz, L., Markowski, M., Sadowski, P., Jakóbczak, A. and Janulin, M. 2015. Creep and recovery characteristics of chicken meat frankfurters. J. Agr. Sci. Tech. 17, 827-835.

Ilayabharathi, D., Sheriff, F.R. and Raj Manohar, G. 2012. Shelf-life of spent chicken sausage and its organoleptic qualities. Tamilnadu J. Veterinary & Animal Sciences 8, 60-67.

Jin, S-K., Choi, J-S. and Kim, G-D. 2017. Effects of bundle type and substitution with spent laying hen surimi on quality characteristics of imitation crabsticks. Korean Journal for Food Science and Animal Resources 37, 200-209.

Jin, S-K., Hur, I.C., Jeong, J.Y., Choi, Y.J., Choi, B.D., Kim, B.G. and Hur, S.J. 2011. The development of imitation crab sticks by substituting spent laying hen meat for Alaska Pollack. Poultry Sci. 90, 1799-1808.

Lengkey, H.A.W., Garnida, D., Siwi, J.A., Edianingsih, P., Wulandari, E. and Pratama, A. 2016. The effect of carrageenan on shelf-life, quality improvement and organoleptic qualities of spent chicken sausages. AgroLife Scientific Journal 5, 115-120.

Nowsad, A.A.K.M., Kanoh, S. and Niwa, E. 2000. Thermal gelation characteristics of breast and thigh muscles of spent hen and broiler and their surimi. Meat Science 54, 169-175.

Peleg, M. and Normand, M.D. 1983. Comparison of two methods for stress relaxation data presentation of solid foods. Rheologica Acta 22, 108-113.

Silva, F.A.P., Estévez, M., Ferreira, V.V.S., Silva, S.A., Lemos, L.T.M., Ida, E.I., Shimokomaki, M. and Madruga, M.S. 2017. Characterization of preserved meat from spent hen and broiler by salting and forced-air drying. Journal of Food Processing and Preservation 41, 1-10.

Sorapukdee, S., Uesakulrungrueng, C. and Pilasombut, K. 2016. Effects of humectant and roasting on physicochemical and sensory properties of jerky made from spent hen meat. Korean J. Food Sci. An. 36, 326-334.

Steffe, J.F. 1996. Rheological Methods in Food Process Engineering. East Lansing, Michigan: Freeman Press.

Wongwiwat, P., Wattanachant, S. and Siripongvutikorn, S. 2009. Effect of phosphate treatments on microbiological, physicochemical changes of spent hen muscle marinated with Tom Yum paste during chilled storage. J. Sci Food Agric. 90, 1293-1299

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