World Applied Sciences Journal 31 (12): 2062-2067, 2014
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2014.31.12.658

Chicken Sausages Formulated with Gelatin from Different Sources: A Comparison of Sensory Acceptability and Storage Stability

[1]S.E. Ch'ng, [1]M.D. Ng, [2]W. Pindi,
[1]O.L. Kang, [1]A. Abdullah and [1]A.S. Babji

[1]Food Science Programme, School of Chemical Sciences and Food Technology,
Faculty of Science and Technology, Universiti Kebangsaan Malaysia,
43600, UKM Bangi, Selangor, Malaysia
[2]School of Food Science and Nutrition, University Malaysia Sabah,
Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia

Abstract: This research is carried out to compare the sensory acceptability, physico-chemical characteristics and oxidative stability of Mechanically Deboned Chicken Meat (MDCM) sausages formulated with gelatin from different sources (namely cold water fish and bovine) partially replacing isolated soy protein (ISP) as binder during chilled storage. Four samples were prepared whereby T1 as control with 4.5% ISP (without gelatin); T2 contained 0.5 % commercial gelatin; T3 contained 4% ISP + 0.5% cold water fish gelatin and T4 contained 4% ISP + 0.5% bovine gelatin. Sensory evaluation with 7-points Hedonic score by 50 untrained panels were carried out at initial stage. All samples were then kept in chilled condition (4°C ± 1°C) and analyzed on 0, 1, 2 and 3 weeks to observe the colour [L* (lightness), a* (redness) and b* (yellowness)], pH, texture (hardness, elasticity) changes and oxidative stability [Thiobarbituric Acid (TBA) profile]. T4 (with bovine gelatin) score higher aroma, taste and overall acceptance as compared to other formulations in sensory evaluation. MDCM sausages with commercial and cold water fish gelatin score significantly highest L* value and lowest a* value throughout the storage periods. TBA and pH value increased sharply due to induction period during first week storage and then remain stable during second week but slightly decreased towards the end of storage periods. The hardness and elasticity increased significantly throughout the storage period. Overall, partially replacing ISP with gelatin into MDCM sausages had exhibited promising improvement in sensory properties and physicochemical stability during storage but not on oxidative profile.

Key words: Gelatin · Cold Water Fish · Bovine · Mechanically Deboned Chicken Meat · Sausages

INTRODUCTION

Mechanically deboned chicken meat (MDCM) is commonly used as a major ingredient in producing comminute meat products [1] such as chicken sausages, frankfurters, burger and etc. MDCM is the meat emulsion obtained during recovery process from the skeleton and bone tissues through mechanical procedure [1]. It is highly oxidized due to its composition which is high in fat and haemoglobin. Though MDCM is a low quality product, it is widely used in the value-added meat product industry to reduce cost and prevent wastage. Although MDCM has relatively low binding and gelation ability [2], it is suitable in emulsified meat products such as sausage and salami that do not required fibrous texture [3]. Emulsifiers such as sodium caseinate, isolated soy protein (ISP) and whey protein concentrate (WPC) are commonly added to improve the texture and acceptability of the end products. Non-meat proteins derived from a variety of plant and animal sources are used extensively as fillers, binders and extenders in meat systems. Non-meat ingredients are useful in comminute meat products because of their functional properties including emulsification, water- and fat- binding capacity,

Corresponding Author: Soo Ee Ch'ng, Food Science Programme, School of Chemical Sciences and Food Technology, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600, UKM Bangi, Selangor, Malaysia. Phone: 60123-4675026, Fax: 603-89213232.

improvement of texture and appearance [4]. In order to optimize the use of such nonmeat proteins and obtain a balance between cost and improving functionality, it is important to understand the interactions between the meat and nonmeat ingredients [5].

Gelatin is a denatured protein derived from collagen by thermo hydrolysis. It serves primarily as a gelling agent in food systems, but it is also used as a thickener, film former, stabilizers, emulsifier, adhesive agent, foaming agent, protective colloid and as a beverage fining agent [6]. Gelatin consists of different amounts of 18 amino acids, where glycine, proline and hydroxyproline are the most abundant. A commercial gelatin sample can be grouped according to its origin and the process of manufacture and most common are Type A and Type B gelatin. Type A gelatins are obtained from skins and bones of different origin through an acid process, giving gelatins with isolectric point (pHI) ranging from 6 to 9.5; type B gelatins are obtained from cattle skin or bones through an alkaline process, giving a pHI range of 4.5 -5.5. The ability of gelatin as a protective colloid and film former can be a good coating. The most valuable property of gelatin is probably its ability to form thermo-reversible gels which gives the gelatin gel it's unique "melt-in-the-mouth" quality [6, 7]. The melting temperature of gelatin gels usually lies around 35-37 ºC, i.e. mouth temperature, making gelatin an important texturing and flavour releasing food ingredient [6]. In general, sensory properties, such as appearance, aroma, mouthfeel and texture, are important attribute in affecting consumer acceptability to sausages. Incorporation of gelatin might improve the sensory acceptability of meat products as compared to "beanny" flavour that commonly from ISP.

The functional properties, thermostability and film forming ability of gelatin are highly dependent on its characteristics, which are related to the species origin (mammalian, cold water fish, warm water fish), wastes origin (bones, skin), animal age (affecting the collagen crosslinking) and severity of the extraction procedure (pH, temperature) [7]. The quality of a fish gelatin is determined mainly by its bloom strength and heat stability (melting and gelling temperature). Certain uses, however, do not require these physical attributes to be as high as those of mammalian gelatins, e.g. encapsulation [7]. In recent years, porcine and bovine gelatins are used in emulsified meat products to improve eating quality and acceptability [8].

Utilizing non-meat protein in sausage processing is very popular. However, there is still much uncertainty about the interactions among the functional ingredients in a complex system such as sausages. Therefore, the main objective of this research is to determine the effects of adding gelatin into MDCM sausage partially replacing ISP. Detail comparison among the sensory acceptability of MDCM sausage at the initial storage and physico-chemical characteristics as well as storage stability were also observed during the three weeks storage at chilled condition (4±1°C).

MATERIALS AND METHODS

MDCM Sausage Preparation: MDCM sausages were manufactured with and without gelatin: T1 = control without gelatin; T2 = 0.5 % commercial brand gelatin; T3 = 0.5 % cold water fish gelatin and T4 = 0.5 % bovine gelatin. MDCM was tempered in a refrigerator (4±1°C). Tempered MDCM was chopped and mixed with other ingredient in a cutter (Hobart Ditosama 55, France). Meat batter was homogenized with the temperature controlled at below 15 °C to prevent emulsion breakdown. The meat batter was stuffed into cellulose casing (ϕ=2.5 cm) and sealed tightly. The sausages were cooked in a temperature controlled convection oven starting at 50°C for 15 min, then 60 °C for 15 min, 70°C for 15 min, 80°C for 15 min and 85°C for 30 min. The sausages were cooled in ice water and the casings were removed. Samples were packed airtight in transparent plastic bags and stored at 4±1 °C prior to further analysis.

Sensory Evaluation: Fifty (50) untrained panellists among Universiti Kebangsaan Malaysia students were chosen to evaluate MDCM sausages with and without gelatin from different source. The sensory attribute, such as color, aroma, taste, texture and overall acceptance were evaluated using 7 hedonic scales, where 7 = like extremely and 1= dislike extremely. The sensory evaluation was carried out at the sensory laboratory. All necessary precautions were considered to ensure each panellist made an independent judgment [9].

Shelf life Study: All treatments of MDCM sausages were packed airtight in transparent plastic bags and stored at 4±1 °C for 0, 1, 2 and 3 weeks until further analysis. Analyses carried out were colour [L* (lightness), a* (redness) and b* (yellowness)], pH, texture (hardness, elasticity) changes and oxidative stability [Thiobarbituric Acid (TBA) profile] to evaluate the storage stability.

Color evaluation was tested using Chromameter Minolta CR-100 Tristimulus Color Analyzer which gave CIELAB color evaluation in the form of lightness (L*), redness (a*) and yellowish (b*). pH value was measured using combined glass electrode pH meter (Mettler Toledo 340, Switzerland). The sausage (5 g each) was homogenized with 50 mL distilled water and pH value was measured.

Textural properties were tested using a texture analyzer (Shimadzu AGS-J 500N, Japan) to measure shear force representing hardness (gf) and elasticity (g) for each treatment. Cylinder core sample was compressed 75 % to their original height using cylindrical probe (ϕ=1.0 cm) at constant cross-head speed 1 mm/s. Texture parameters, such as hardness and elasticity, were recorded.

Thiobarbituric acid (TBA) value was determined using extraction method [10]. Sausage (0.5 g each) was homogenized in 2.5 ml TBA/TCA solution (0.02M TBA + 15% TCA). The mixture was incubated in boiling water batch (95 °C, 10 min). The mixture was centrifuged (5000 rpm, 25 min). Finally, the absorbance of the supernatant was measured using spectrophotometer at 532nm against blank (mixture solution without meat). TBA value (mg malonaldehyde/kg sample) was obtained by multiplying O. D. (Optical Density) value with the factor of 2.77.

Statistical Analysis: All experiments were replicated three times and statistical analysis was performed using SAS Ver. 6.12. Statistical significant differences among treatments were indicated at 95 % confidence level.

RESULT AND DISCUSSION

Sensory Evaluation: Sensory characteristics such as colour, aroma, taste, hardness, elasticity, juiciness and overall acceptance were evaluated by 50 untrained panellists. Figure 1 clearly showed the sensory attributes of MDCM sausages prepared with and without gelatin. There was no significant difference statistically among all the treatments for all the attributes. However, formulation T4 with added 0.5% bovine gelatin had slightly higher score for aroma, taste and overall acceptance except colour, hardness and elasticity. The results indicated that the panels showed preferences for particular formulations but could not detect any differences among the treatments. Overall, all four formulations were competitive and acceptable among the consumers.

Colour is a very important attribute and is closely linked to the consumer acceptance. Table 1 clearly showed that T3 with 0.5% fish gelatin scored significantly

Table 1: Physico-chemical change in MDCM sausages with and without gelatin during three weeks chilled storage at 4 ±1 °C

Parameter	Storage time (week)	T1	T2	T3	T4
pH	0	$^{C}6.60\pm0.01_{a}$	$^{C}6.57\pm0.02_{b}$	$^{C}6.57\pm0.01_{b}$	$^{C}6.63\pm0.03_{a}$
	1	$^{A}7.11\pm0.04_{a}$	$^{A}7.11\pm0.06_{a}$	$^{A}7.13\pm0.02_{a}$	$^{A}7.16\pm0.01_{a}$
	2	$^{B}7.00\pm0.06_{ab}$	$^{B}6.91\pm0.03_{c}$	$^{B}6.97\pm0.04_{bc}$	$^{B}7.06\pm0.01_{a}$
	3	$^{D}6.31\pm0.07_{b}$	$^{C}6.51\pm0.07_{a}$	$^{D}6.45\pm0.05_{a}$	$^{D}6.49\pm0.10_{a}$
Lightness, L*	0	$^{B}59.33\pm0.55_{b}$	$^{AB}60.35\pm0.54_{b}$	$^{A}62.43\pm0.20_{a}$	$^{AB}59.85\pm0.68_{b}$
	1	$^{B}58.31\pm0.97_{c}$	$^{AB}60.32\pm0.28_{b}$	$^{A}63.12\pm0.33_{a}$	$^{A}60.98\pm0.46_{b}$
	2	$^{B}59.35\pm0.73_{c}$	$^{A}60.88\pm0.12_{b}$	$^{A}62.68\pm0.24_{a}$	$^{B}59.39\pm0.94_{c}$
	3	$^{B}58.92\pm0.34_{b}$	$^{B}59.29\pm0.99_{b}$	$^{A}62.04\pm0.95_{a}$	$^{AB}60.38\pm0.63_{b}$
Redness, a*	0	$^{B}3.54\pm0.06_{a}$	$^{A}3.48\pm0.11_{b}$	$^{B}3.07\pm0.15_{c}$	$^{A}3.86\pm0.31_{a}$
	1	$^{A}3.74\pm0.12_{b}$	$^{A}3.56\pm0.13_{b}$	$^{A}3.53\pm0.26_{b}$	$^{A}4.06\pm0.12_{a}$
	2	$^{A}3.77\pm0.11_{a}$	$^{A}3.46\pm0.09_{ab}$	$^{AB}3.26\pm0.02_{b}$	$^{A}3.69\pm0.30_{a}$
	3	$^{AB}3.61\pm0.09_{b}$	$^{A}3.54\pm0.13_{b}$	$^{AB}3.38\pm0.20_{b}$	$^{A}3.98\pm0.12_{a}$
Yellowness, b*	0	$^{A}16.9\pm0.88_{a}$	$^{A}14.9\pm0.37_{b}$	$^{A}16.3\pm0.66_{a}$	$^{B}12.8\pm0.42_{c}$
	1	$^{A}17.1\pm0.59_{a}$	$^{A}15.3\pm0.46_{b}$	$^{A}16.1\pm0.12_{b}$	$^{B}12.9\pm0.41_{c}$
	2	$^{A}16.6\pm0.98_{a}$	$^{A}15.1\pm0.31_{bc}$	$^{A}15.8\pm0.69_{ab}$	$^{B}13.1\pm0.24_{c}$
	3	$^{A}17.0\pm0.67_{a}$	$^{A}15.4\pm0.57_{b}$	$^{A}16.1\pm1.13_{a}$	$^{B}12.9\pm0.57_{c}$
Hardness (gf)	0	$^{B}230.7\pm3.74_{b}$	$^{B}285.5\pm9.49_{a}$	$^{B}291.5\pm6.45_{a}$	$^{C}323.1\pm4.48_{a}$
	1	$^{A}294.9\pm9.60_{b}$	$^{B}324.3\pm6.55_{ab}$	$^{AB}321.4\pm7.04_{ab}$	$^{BC}342.4\pm8.38_{a}$
	2	$^{A}305.1\pm8.17_{b}$	$^{A}375.9\pm4.94_{a}$	$^{AB}340.9\pm5.03_{a}$	$^{AB}380.9\pm2.88_{a}$
	3	$^{A}339.5\pm9.31_{a}$	$^{A}391.4\pm5.70_{a}$	$^{A}370.6\pm9.68_{a}$	$^{A}399.3\pm5.25_{a}$
Elasticity (N/cm)	0	$^{A}941.7\pm7.74_{a}$	$^{A}841.7\pm5.04_{b}$	$^{B}816.7\pm4.43_{b}$	$^{B}454.2\pm7.22_{c}$
	1	$^{A}1091.7\pm1.34_{a}$	$^{A}933.3\pm2.92_{b}$	$^{AB}950.0\pm6.29_{b}$	$^{AB}550.0\pm7.63_{c}$
	2	$^{A}1033.3\pm5.83_{a}$	$^{A}850.0\pm6.60_{b}$	$^{AB}908.3\pm2.92_{ab}$	$^{AB}540.0\pm5.00_{c}$
	3	$^{A}1041.7\pm7.74_{a}$	$^{A}933.3\pm4.08_{a}$	$^{A}966.6\pm8.15_{a}$	$^{A}633.3\pm6.38_{b}$

Means with different superscripts($^{A-C}$) in each column differ significantly ($P < 0.05$), n = 3 Means with different subscripts$_{(a-c)}$ in each row differ significantly ($P < 0.05$), n = 3

T1: Control without gelatin, T2: 0.5 % commercial gelatin; T3: 0.5 % cold water fish gelatin; T4: 0.5 % bovine gelatin, gf: gram force.

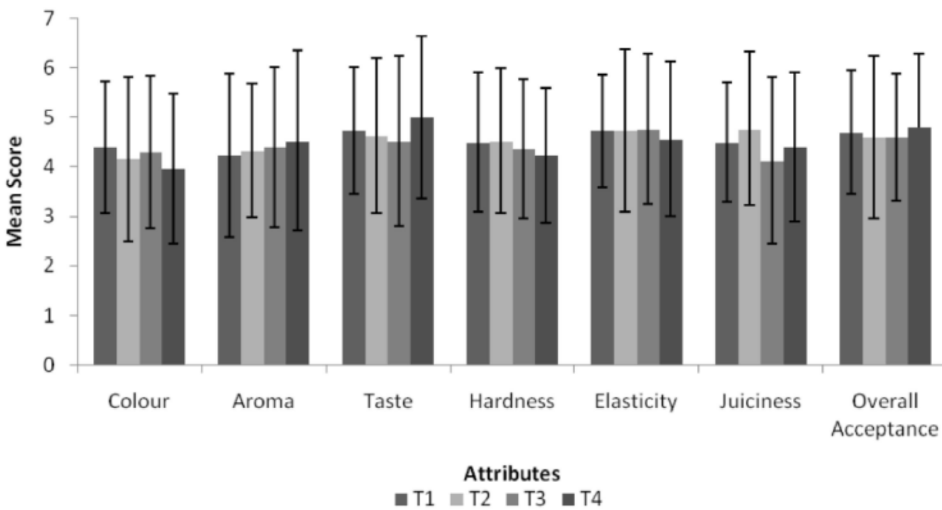

Fig. 1: Sensory attributes of MDCM sausages with and without gelatin T_1: Control without gelatin, T_2: 0.5 % commercial gelatin; T_3: 0.5 % cold water fish gelatin; T_4: 0.5 % bovine gelatin. *Colour [L* (lightness), a* (redness) and b* (yellowness)]*

highest L* 62.04-63.12) and lowest a* (3.07-3.53) value while T4 with 0.5% bovine gelatin scored the lowest b* (12.80-14.16) value. T4 had also recorded lowest L* value at (59.39-60.98) and highest a* value (3.69-4.06). Differences in colour and its stability in value-added meat products are commonly due to the raw ingredients added in the formulation [11]. Degree of redness is the general parameter that has been used as colour indicator for the freshness of meat and meat products. Gelatin from bovine source are generally darker in nature as compared to the fish gelatin used in this research.

Meat sausages with higher a* value is desirable and score highest consumer acceptance [12]. According to [13], meat sausages with L* value between 62.3 and 68.5 were highly accepted by consumers. However, sausages made from mechanically deboned chicken meat are generally darker in colour due to the high content of haemoglobin and ferrous. The results obtained in this research had exhibited an interesting trend whereby, L* values generally decline while a* value generally increase throughout the storage. However, there was no significant changes ($P > 0.05$) in b* values over the storage period. Increase in a* value could refer to lipid and pigment oxidation during storage. Redness is viewed as a more important parameter in meat products and the importance of yellowish remained unclear [14].

pH Value: pH value is commonly correlated to colour parameter. In this work, however, there was no correlation between pH values and colour parameter. MDCM sausages with higher pH (pH > 6.0) value were lighter in colour with more intense yellow taint. There was slightly increased in pH value during the first week storage and then declined during subsequent storage periods. Increase in pH value could attribute to metabolites accumulation through bacterial action on protein and amino acids during storage [15,16]. On the other hand, the increase in pH value could refer to meat protein breakdown during storage [17].

Textural Analysis: Textural characteristics are one of the most important aspects affecting the consumer acceptability of particular meat products [18]. The higher hardness value was observed in MDCM sausages with gelatin. The highest hardness value at 323.08 gf was observed in MDCM sausages with bovine gelatin. However, these higher hardness values do not necessarily mean better in quality. From the earlier sensory evaluation reported, there is no significant differences among all the formulations in the attributes of hardness at the initial storage period.

However, from the instrumental textural properties measured, there was a significant difference ($P < 0.05$) in hardness comparing MDCM sausages with and without gelatine during the initial stage of storage. The higher hardness values among MDCM sausages with gelatin could be attributing to water/fat availabilities and binding properties. It could be an indication whereby gelatin could assist in binding meat pieces and resulted in meat products with more homogenized texture. There was significant increment in hardness during the storage period. These results are supported by the significant

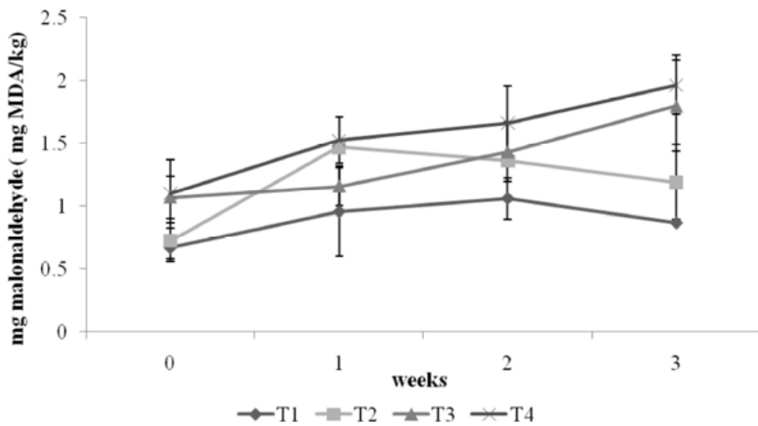

Fig. 2: TBA values for 4 samples in 3 weeks storage. T_1: Control without gelatin, T_2: 0.5 % commercial gelatin; T_3: 0.5 % cold water fish gelatin; T_4: 0.5 % bovine gelatin (n=3).

decrement in elasticity. Increase in hardness and could be contributed by the protein granular ruptured during storage. On the other hand, the increase in hardness could also due to the moisture loss during storage [19].

Thiobarbituric Acid (TBA) Value: The formation of thiobarbituric acid reactive substances, TBARS (such as malondialdehyde MDA) was due to the breakdown of hydroperoxides [20]. Cooking or heating process in oven prior to refrigeration is one of the most dominant prooxidative processes causing accelerated hydroperoxide generation and decomposition in samples. Its effects may last until the early stages of refrigeration storage [21]. Figure 2 clearly showed the TBA values for 4 samples in 3 weeks storage. There were significant increments ($P < 0.05$) in TBA value among the treatments throughout the whole storage period. This phenomenon could be contributed by lipid oxidation during storage [22]. Significant higher ($P < 0.05$) TBA value among MDCM sausage with gelatin replacement by 0.5% as compared to formulation with 4.5% ISP. Formulation with 0.5% bovine gelatin showed the highest TBA value during the 3 weeks storage at chilled condition while Control with ISP showed the lowest TBA value.

Lower TBA value represented a better formulation as it is more susceptible to oxidation; however, all four treatments were still safe to be consumed after 3 weeks storage as the TBA values were still within the acceptable level [15]. Rancid flavour had been reported that can only be detected in chicken at the TBA value of 1.0-2.0 mg malonaldehyde/kg sample. However, this value cannot be considered as the starting point of reference for the production of rancid flavour in meat products because many factors can affect the TBA value. However, the consumption limit of malonaldehyde is 7-8 mg/kg and therefore the sausage still safe to consume after 3 weeks storage [23].

CONCLUSION

As the conclusion, incorporation of gelatin into Mechanically Deboned Chicken Meat (MDCM) sausages had successfully improved the sensory properties and physicochemical stability during storage. However, TBA profiles were compromised with the incorporation of gelatin in the formulations. Further researchers should be carried out in more details studying the oxidative reaction in emulsion types meat products as the formation of malonaldehyde should not be used as the only indicator concluding the oxidative stability in meat products.

REFERENCES

1. Pussa, T., P. Raudsepp, P. Toomik, R. Pallin, U. Maeorg, S. Kuusik, R. Soidla and M. Rei, 2009. A study of oxidation products of free polyunsaturated fatty acids in mechanically debonded meat. Journal of Food Composition Analyses, 22: 307-314.
2. Mielnik, M.B., K. Aaby, K. Rolfsen, M.R. Ellekjae and A. Nilsson, 2002. Quality of comminuted sausages formulated from mechanically deboned poultry meat. Meat Science, 61: 73-84.
3. Daros, F.G., M.L. Masson and S.C. Amico, 2005. The influence of the addition of mechanically debonded poultry meat on the rhelogical properties of sausage. Journal of Food Engineering, 68: 185-189.

4. Pietrasik, Z. and E.C.Y. Li-Chan, 2002. Binding and textural properties of beef gels as affected by protein, kappa-carrageenan and microbial transglutaminase addition. Food Research International, 35: 91-98.
5. Barbut, S., 2006. Effects of caseinate, whey and milk powders on the texture and microstructure of emulsified chicken meat batters. LWT Food Science and Technology, 39: 660-664.
6. Segtnan, V.H., K. Kvaal, E.O. Rukke, R.B. Schuller and T. Isaksson, 2003. Rapid assessment of physico-chemical properties of gelatin using near infrared spectroscopy. Food Hydrocolloids, 17: 585-592.
7. Gomez-Estaca, J., B. Gimenez, P. Montero and M.C. Gomez-Guillen, 2009 Incorporation of antioxidant borage extract into edible films based on sole skin gelatin or a commercial fish gelatin. Journal of Food Engineering, 92: 78-85.
8. Herpandi, Huda, N. and F. Adzitey, 2011. Fish bone and scale as a potential source of Halal gelatin. Journal of Fish Aquatic Science, 6(4): 379-389.
9. Aminah, A., 2000. Prinsip Penilaian Sensori. Bangi. Penerbit Universiti Kebangsaan Malaysia.
10. Buege, A.J. and S.D. Aust, 1978. Microsomal lipid peroxidation. Methods Enzymology. 52: 302-310.
11. Cofrades, S., E. Hughes and D.J. Troy, 2000. Effects of oat fiber and carageenan of the texture of frankfurters formulated with low and high fat. European Food Research Technology, 211(1): 19-26.
12. Ressurreccion, A.V.A., 2004. Sensory aspects of consumer choices for meat and meat product. Meat Science, 66: 11-20.
13. Dingstad, G.I., E. Kubberod, T. Naes and B. Egelandsdal, 2005. Critical quality constraints of sensory attributes in frankfurter-type sausages, to be applied in optimization models. LWT Food Science and Technology, 38: 665-676.
14. Juncher, D., R. Birgitte, T.B. Hansen, P. Henckel, A. Karlsson, L.H. Skibsted and G. Bertelsen, 2003. Effect of pre-slaughter physiological conditions on theoxidative stability of color and lipid during chill storage of sliced, retail packed roast ham. Meat Science. 63: 151-159.
15. Kandeepan, G., A.S.R. Anjaneyulu, N. Kondaiah, S.K. Mendiratta and R.S. Rajkumar, 2011. Evaluation of quality and shelf life of buffalo meat keema at refrigerated storage. Journal of Food Science and Technology. doi: 10.1007/s13197-011-0454-5.
16. Bhat, Z.F., P. Kumar and S. Kumar, 2011. Effect of skin, enrobing and refrigerated storage on the quality characteristics of chicken meat balls. Journal of Food Science and Technology doi: 10.1007/s13197-011-0414-0.
17. Kumar, D. and V.K. Tanwar, 2011. Effects of incorporation of ground mustard on quality attributes of chicken nuggets. Journal of Food Science and Technology, 48(6): 759-762.
18. Hsu, S.Y. and H.Y. Chung, 1998. Effect of processing factors on qualities of emulsified meatball. Journal of Food Engineering, 36: 337-347.
19. Candogan, K. and N. Kolsarici, 2003. Storage stability of low-fat beef frankfurters formulated with carrageenan or carrageenan with pectin. Meat Sci., 64: 207-214.
20. Chan, K.W., N.M.H. Chong, S. Iqbal, S.E. Ch'ng and A.S. Babji, 2012. Preparation of clove buds deodorized aqueous extract (CDAE) and evaluation of its potential to improve oxidative stability of chicken meatballs in comparison to synthetic and natural food antioxidants. Journal of Food Quality, 35: 190-199.
21. Jo, C., J.I. Lee and D.U. Ahn, 1999. Lipid oxidation, color changes and volatiles production in irradiated pork sausage with different fat content and packaging during storage. Meat Science, 51: 355-361.
22. Sudheer, K., P.K. Mandal, C. Das, U.K. Pal, H.T. Santoshkumar and V.K. Rao, 2011. Development of restructured chicken block utilizing gizzard and its refrigerated storage stability. Journal of Food Science and Technology, 48(1): 96 -101.
23. Karpiñska-Tymoszczyk, M., 2011. The effect of oil-soluble rosemary extract, sodium erythorbate, their mixture and packaging method on the quality of Turkey meat balls. Journal of Food Science and Technology. doi: 10.1007/s13197-011-0359-3.