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# Effect of Kappa Carrageenan on Physicochemical Quality and Sensory Attributes in Development of Chicken Meat Bites

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## ABSTRACT

Many studies were conducted on the use of carrageenan as fat replacer but lacks useful information for its functional activity in meat products. Therefore, aim of this study was to understand the functional effect of Kappa carrageenan on the quality of chicken meat bites. To achieve this goal, Kappa carrageenan was added at 0, 0.5, 0.75 and 1.0 % levels for control, T1, T2 and T3 products, respectively. Control bites contained 5 % added fat while treated samples were processed without added fat and the level of added fat of control sample was replaced with lean meat for the treatment groups. Results indicated addition of Kappa carrageenan improved the cooking yield, emulsion stability and emulsion and cooked product pH up to 0.75 % added level. However, addition of Kappa carrageenan increased shear force value, differences were non-significant. Colour coordinator, yellowness (b-value) and Chroma values increased significantly while antioxidant parameters for ABTS activity was little affected. With regards to sensory quality, T1 and T2 samples showed nearly similar but higher scores for all attributes than T3 sample. Thus, it was attributed that increasing of concentration of kappa carrageenan above 0.75 % reduced sensory scores for all attributes. Finally, it was concluded that addition of kappa carrageenan in development of chicken meat bites could help in reduction of fat level besides improving antioxidant activity, colour stability and consumer acceptability of finished products. Thus, it was recommended to use upto 0.75% level of kappa carrageenan in development of chicken meat bites for its fullest utilization of beneficial effects.

**Keywords:** *Kappa carrageenan, Antioxidant activity, Sensory Attributes, Chicken Meat Bites*

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## INTRODUCTION

Kappa carrageenan (*Kappaphycus alvarezii*) though commonly used as fat replacer but at present scientific community is showing greatest interest towards functional activity of this potential ingredient. It forms gel when reacts with calcium or potassium salts. In the presence of calcium, kappa carrageenan forms stiff and brittle gels. But in the presence of potassium salts, kappa carrageenan forms very firm and elastic gels. Thus, diverse kinds of carrageenan are formed using this species of algae. The kappa (I and II), iota and lambda vary in numbers and positions of the sulphate groups on the galactose dimer (Bloukas *et al.,* 1997; Van de Velde, 2002). Kappa carrageenan is a major hydrocolloid variety of red algae which has been extensively investigated for its vast array of bioactivities such as anticoagulant, antiviral, cholesterol-lowering effects, immunomodulatory activity, and antioxidant activity (Necas and Bartosikova, 2013). Kappa carrageenan possesses promising functional activity both *in-vitro* and *in-vivo*, with promising potential to be developed as therapeutic agents.

It has been reported that kappa carrageenan increase the cooking yield and hardness in low-fat emulsified meatballs (Hsu and Chung, 200), improve water retention in sausage items (Lin and Ketton, 1998), improvise textural properties of beef patties (Pietrasik and Jarmoluk, 2003; Prabhu and Sebranek, 1997; Shand *et al.,* 1994) and also enhanced sensory properties of cooked ham (Huang *et al.,* 1997). At an alkaline pH and in the presence of salt, kappa carrageenan was reported to improve WHC and colour stability of the sausage (Bloukas *et al.,* 1997). Bater *et al.* (1992) found that kappa carrageenan caused an increase in yield, sliceability and rigidity and a decrease in expressible juice in roasted turkey breasts. It was also found to increase the hardness of meat batters when replacing fat by water gum solution (Foegeding and Ramsey, 1986, 1987). DeFreitas *et al.* (1997) reported increased gel strength and water retention when adding kappa carrageenan to salt soluble meat protein gels.

Functional chicken meat products like burger patties, nuggets, bites, sausages, salamis, koftas etc getting wider market demand in the recent years. Functional chicken meat bite is an emulsion based meat product usually developed using health promoting ingredients alongwith other ingredients.Chicken meat bites are generally processed by steam cooking, broiling (baking) and more recently by microwave cooking methods. Since, there is very limited literature found on the use of Kappa carrageenan as functional ingredients in development of chicken meat products, this present work was conducted to find out the effect of kappa-carrageenan on the physicochemical and sensory attributes of chicken meat bites.

## MATERIALS AND METHODS

### Sources of Raw Materials

***Source of meat:*** Spent chicken of above 50 weeks age group of both the sexes were selected from Experimental layer and broiler farms of ICAR-CARI, Izatnagar, Bareilly. The birds were slaughtered as per standard slaughtering techniques in the Experimental Poultry Processing Plant of Division of PHT, ICAR-CARI, Bareilly, India. Immediately after slaughtering, the carcasses were shifted to the laboratory for processing. For this, skin of the carcasses was removed, hot deboned, packed in self-sealing LDPE bags, labeled and finally, kept overnight at refrigeration temperature (4 ± 1 ºC). The meat was then shifted to deep freezer and stored at -18 ± 2ºC until further use.

***Spice mix:*** The spices were procured from local market of Bareilly, India. After removal of extraneous matters, the spices were oven

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dried at 50 ± 2°C for 2 h. The ingredients were ground mechanically and sieved through a fine (U.S.S. #30) mesh screen. The powders so obtained were mixed in suitable proportion to obtain a spice mix for marinade. The spice mix was stored in a PET (polyethylene terephthelet) jar for subsequent use.

***Condiments (green curry stuff):*** Condiments used in the study (onion: garlic: ginger = 3:1:1; w/w/w) were purchased from local market of Bareilly, India. After peeling off the external coverings of fresh and clean onion, garlic and ginger, they were chopped-off into small pieces and ground in a mixture grinder to make fine paste of each component, separately. All the ingredients were mixed well in the above mentioned proportion for use in the experiments.

***Table salt, sodium tri-polyphosphate, sodium nitrite etc:*** Table salt (Tata Chemicals Ltd., Mumbai, India), sodium tri-polyphosphate, citric acid, sodium ascorbate, sodium nitrite etc were procured from SRL Pvt. Ltd., New Delhi, India, wheat flour and other ingredients used in preparation of emulsion.

***Preparation of chicken meat bites:*** About 2.0 kg of lean meat was minced through a 8 mm grinding plate in a meat grinder (Hobart, USA). The minced meats were divided into four different batches of 0.5 kg each. The Kappa carrageenan was added @ 0. 0.5, 0.75 and 1.0% level for control, $T_1$, $T_2$ and $T_3$, respectively. The added carrageenan for all the treatment groups was replaced with the lean meat. All batches of samples were mixed gently with hand and kept for 30 min at 4 ±1ºC. These were then separately mixed with the curing ingredients, fillers, binders and other seasonings in a Hobbart paddle type mixer for 3 min. The samples were filled-up in aluminium molds and finally steam cooked for 35 min. The developed products were cooled to room temperature, chilled and then sliced into bites. Each group of bites was packaged in colourless LDPE bags for evaluation of different physico-chemical and sensory quality parameters.

**Analytical Procedures**

***Emulsion stability:*** The emulsion stability was determined by the method of Baliga and Madaiah (1970). About 25 g of meat sample was taken in poly ethylene bag and heated in a thermostatically controlled water bath at 80ºC for 20 min. Then the exudate was drained out and the cooked mass was weighed. The percentage of cooked mass was expressed as emulsion stability. Cooking loss of a product is inversely proportional to its emulsion stability.

***Emulsion and product pH:*** The pH value of emulsion and product were determined by the method of Trout *et al.* (1992). Homogenates were prepared by blending 10 g sample with 50 ml distilled water for 1 min. pH of homogenates was recorded by digital pH meter (Eutech, pH 2700).

***Cooking yield:*** The weight of emulsion before extrusion, weight of emulsion remaining after extrusion and product weight were recorded. Cooking yield was calculated using the formula as under. Cooking yield (%) = weight of product obtained/ (weight of emulsion before extrusion – weight of emulsion remaining after extrusion) x 100.

***W-B shear force value (WBSFV):*** The shear force value of the chicken meat bites was measured following the method of Berry and Stiffler (1981) with slight modification. For each measurement a sample size of 1.5 × 1 ×1 $cm^3$ (L×W×H) was placed in the Warner-Bratzler shear blade attached to the apparatus (Model 81031307, G.R. Elect. Mfg. Co. USA), run and finally taken reading. Ten observations were recorded for each sample to obtain the value of shear force in $kg/cm^2$.

***Lovibond Tintometer colour:*** The colour profiles of all the samples were measured using Lovibond tintometer (Model F, Greenwich, U.K.). Two different samples of each product were analyzed. The sample colour was matched by adjusting red (a) and yellow (b) units and the corresponding colour units were recorded. The 'Hue' and 'Chroma' values were determined by using formula, $(\tan^{-1})$ b/a (Little, 1975) and $(a^2 + b^2)^{1/2}$ (Froehlich *et al.* 1983) respectively, where a, red unit; b, yellow unit.

***$ABTS^+$ (2-2-azinobis-3ethylbenthiazoline-6-sulphonic acid) radical scavenging activity:*** The spectrophotometric analysis of $ABTS^+$ radical scavenging activity was determined according to method of Biswas *et al.* (2015). This method is based on the ability of antioxidants to quench the long-lived ABTS radical cation, a blue/green chromophore with characteristic absorption at 734 nm, in comparison to that of standard antioxidants. The $ABTS^+$ activity was calculated by using formula:

$ABTS^+$ activity (% inhibition) = $[(At_0 - At_{20})/At_0] \times 100$.
Where, $At_0$= absorbance at 0 min and $At_{20}$ = absorbance after 20 min.

***1, 1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity:*** The ability to scavenge 1, 1-diphenyl-2picrylhydrazyl (DPPH) radical was estimated following the method of Biswas *et al.* (2015) with slight modifications. In modified method, 5 g of sample was triturated with 20 ml of ethanol for 2 min, filtered through Whatman filter paper No 42 and then, 1 ml of the filtrate was mixed with 1ml of 0.1M Tris-HCl buffer (pH 7.4) and 1ml of DPPH reagent (250 µM) in test tubes. The content was gently mixed and then the absorbance in time t=0 min (t0) was measured at 517 nm. The sample tubes were also incubated at room temperature (27 ± 1ºC) under dark for measurement of absorbance in time t=20 min ($t_{20}$). The free radical scavenging activity was calculated as per following:
Scavenging activity (%) = $100-(At_{20}/At_0) \times 100$.

***Sensory evaluation:*** A six member experienced panel of judges consisting of teachers and postgraduate students of Poultry Science Discipline, ICAR-IVRI, Izatnagar were evaluated the samples for the attributes of appearance and colour, texture, flavour, juiciness and overall acceptability using an 8 point descriptive scale (Keeton 1983), where 8=extremely desirable and 1=extremely undesirable.

Three sittings (n=21) were conducted for each replicate and at each storage time on samples warmed in a microwave oven for 20 sec. Tap water at room temperature was provided to each panel member to rinse the pallet before tasting of each sample.

***Statistical analysis:*** Data were analysed statistically using standard software packages version SPSS-16 as developed by Snedecor and Cochran (1994). Duplicate samples were drawn for each parameter and the experiment was replicated thrice (n=6). Sensory evaluation was performed by a panel of seven members judges three times, so total observations being 21 (n=21).) Data generated for the Experiment was analyzed using one-way ANOVA, homogeneity test and Tukey's Multiple Range Test (Tukey, 1949) for comparing the means to find the effects between treatments. The statistical significance was expressed at $p < 0.05$.

## RESULTS AND DISCUSSIONS

Mean and standard error mean (SEM) of various physicochemical, antioxidant activity and sensory quality parameters of precooked spent chicken meat bites processed using different levels of kappa carrageenan are presented in Table 1 and Table 2.

***Physicochemical parameters:*** Result revealed that use of different level of kappa carrageenan had significant ($p<0.05$) effect on different physicochemical parameters. The cooking yield was significantly higher in all treated samples than control (Table 1). Similarly, the emulsion stability and product pH of the treated products is significantly higher than the control sample. Amongst the treatment groups, emulsion pH of $T_2$ and $T_3$ sample though recorded higher than $T_1$ but did not differ significantly ($p>0.05$). Numerically higher WBSFV was observed amongst the treated samples but value differed non-significantly from control. With regards to Lovibond tintometer Color redness (*a*-value) and *Hue* angel did not differ significantly whereas yellowness (*b*-value) and *Chroma* of $T_2$ sample were significantly greater ($p<0.05$) than other samples.

Nayak *et al.* (2016) also reported a significant ($p<0.05$) difference in the cooking yield of chevon patties between control and treatments with increasing carrageenan level which might be due to ability of carrageenan to form complexes with water and

**Table 1: Different physicochemical and antioxidant property in chicken meat bites using kappa carrageenan at different**

| Parameters | Control | $T_1$ | $T_2$ | $T_3$ | SEM | P value |
|---|---|---|---|---|---|---|
| **Physicochemical Parameters** | | | | | | |
| Cooking Yield (%)# | 90.51$^{a}$ | 95.63$^{b}$ | 96.21$^{b}$ | 97.22$^{b}$ | 0.92 | 0.012 |
| Emulsion Stability (%) | 82.76$^{a}$ | 92.54$^{b}$ | 92.37$^{b}$ | 91.88$^{b}$ | 0.94 | 0.001 |
| Emulsion pH | 6.26$^{a}$ | 6.31$^{ab}$ | 6.42$^{b}$ | 6.43$^{b}$ | 0.02 | 0.001 |
| Product pH | 6.27$^{a}$ | 6.47$^{b}$ | 6.46$^{b}$ | 6.48$^{b}$ | 0.03 | 0.001 |
| WBSFV (kg/cm$^2$) | 0.24 | 0.23 | 0.27 | 0.27 | 0.02 | 0.259 |
| **Lovibond tintometer colour** | | | | | | |
| Redness(a-value) | 2.55 | 2.65 | 2.62 | 2.55 | 0.05 | 0.373 |
| Yellowness(b-value) | 6.53$^{a}$ | 6.63$^{ab}$ | 6.78$^{b}$ | 6.62$^{ab}$ | 0.04 | 0.010 |
| Hue | 1.20 | 1.19 | 1.20 | 1.20 | 0.01 | 0.605 |
| Chroma | 7.01$^{a}$ | 7.14$^{ab}$ | 7.27$^{b}$ | 7.09$^{ab}$ | 0.04 | 0.004 |
| **Antioxidant activity** | | | | | | |
| ABTS$^{+}$ | 43.55$^{a}$ | 47.74$^{ab}$ | 48.78$^{b}$ | 54.16$^{c}$ | 1.08 | 0.001 |
| DPPH | 28.36 | 32.27 | 30.34 | 29.58 | 1.61 | 0.410 |

n=6, #n=3 Mean with different superscript row-wise differ significantly at ($p < 0.05$) T1= 0.5%, T2=0.75% and T3=1.0 % of kappa carrageenan

**Table 2: Different sensory quality parameters in chicken meat bites using kappa carrageenan at different level.**

| Parameters | Control | $T_1$ | $T_2$ | $T_3$ | SEM | P value |
|---|---|---|---|---|---|---|
| Colour & appearance | 6.79$^{a}$ | 7.33$^{b}$ | 7.48$^{b}$ | 7.24$^{ab}$ | 0.11 | 0.001 |
| Flavour | 6.64$^{a}$ | 7.33$^{b}$ | 7.38$^{b}$ | 7.24$^{b}$ | 0.11 | 0.001 |
| Texture | 6.67$^{a}$ | 7.36$^{b}$ | 7.29$^{b}$ | 7.21$^{b}$ | 0.11 | 0.001 |
| Juiciness | 6.95$^{a}$ | 7.36$^{b}$ | 7.33$^{b}$ | 7.17$^{ab}$ | 0.10 | 0.013 |
| Overall Acceptability | 6.79$^{a}$ | 7.26$^{b}$ | 7.29$^{b}$ | 7.17$^{ab}$ | 0.11 | 0.006 |

n=21,*Based on 8-point descriptive scale (where 8=extremely desirable and 1= extremely undesirable). Mean with different superscript row-wise differ significantly at ($p < 0.05$) T1= 0.5%, T2=0.75% and T3=1.0 % of kappa carrageenan.

protein (Egbert *et al.,* 1991) which improves water retention and cooking yield. Carrageenan reduced cooking losses in meat products (Chatli, 2001). Nayak *et al.* (2016) also observed that emulsion stability increased significantly with the incorporation of 0.6 and 0.9% levels of carrageenan in chevon patties. This might be due to comparatively better binding and gelling properties of carrageenan at particular level. Nayak and Pathak (2016) reported non- significant difference in the redness and yellowness value didn't among the control and treated sample incorporated with carrageenan in chevon patties. But contradictory result was found in this study since yellowness value differed significantly. It could be attributed to dilution of color pigment due to addition of yellow component and also compensatory water in the formulation of low fat chicken bites. Fat reduction results in darker sausages with less red color, but has no effect on yellowness (Hughes *et al.,* 1998). Addition of water in low-fat meat products resulted in a higher dilution of color and consequently less red color (Morin *et al.,* 2002).

***Antioxidant activity:*** Results in Table 1 revealed that with the increase in concentration of kappa carrageenan the product showed significant ($p<0.01$) increase of $ABTS^+$ activity where $T_3$ scored highest followed by $T_2$ and $T_1$ respectively but values for DPPH activity were non-significant ($p>0.05$) among the treatments. Higher ABTS activity of treated samples could be attributed to the presence of polysaccharides and some other bioactive compounds *Kappaphycus alvarezii* (Matanjun *et al.,* 2008). The contribution of other phenolic compounds cannot be ignored (Song *et al.,* 2010) which have different antioxidant capacity (Tatiya *et al.,* 2011). The antioxidant activity of all carrageenans has been studied. Kappa-Carrageenan exhibited the highest antioxidant and free radical scavenging activity (Necas and Bartosikova 2013).

***Sensory evaluation:*** Mean and standard error mean (SEM) of sensory quality parameters of precooked chicken meat bites processed using different levels of kappa carrageenan are presented in Table 2. Data revealed that highly significant effect in all sensory attributes amongst the control and treated samples. Sensory evaluation parameters revealed that the $T_1$ and $T_2$ sample show significant higher ($P<0.01$) scores for all sensory attributes *viz.,* colour and appearance, flavour, texture, juiciness and overall acceptability where $T_3$ sample show significant difference only in flavour and texture quality parameters. Foegeding and Ramsey (1986), Mittal and Barbut (1994) and Blouskas *et al.* (1997) observed that carrageenan improved the sensory properties of low fat meat products comparable to that of high fat (control) products. Similar observation was reported by Biswas *et al.* (2016) and according to these authors addition of broken wheat and carrageenan in low salt chicken meat nuggets improved acceptability for all sensory attributes. Chatli (2001) studied that overall acceptability of low fat pork patties were maxuimum at 0.5% level of carrageenan and differed significantly from 0.25 and 0.75% levels. Carrageenan was reported to improve juiciness in low fat beef patties (Egbert *et al.*, 1991). Naruka (2005) also observed the highest score for juiciness at 0.75 % incorporation in pork nuggets. These findings are in the accordance with the results of Indumathi *et al.* (2011) in low-fat chevon patties. Pannin (1974) also reported bitter off flavor in the meat products incorporated with higher concentration of carrageenan. Huffman *et al.* (1991) also reported the similar findings in low fat beef patties. A low texture score of low-fat chicken nuggets at 0.9% carrageenan is also confirmed by respective shear force values. It could also be explained by maximum fat mimicing property of carrageenan at a particular level (Wallingford and Labuza, 1983). Kumar and Sharma (2004) also reported an improvement in texture of low-fat ground pork patties with incorporation of 0.5% carrageenan as compared to 0.25 and 0.75% carrageenan level.

## CONCLUSION

It was found that addition of 0.75% kappa carrageenan was most suitable in development of good quality chicken meat bites since it had desirable properties on different physicochemical and sensory quality parameters of chicken meat bites.

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**ETHICS STATEMENT:** Not Applicable

## REFERENCES

Baliga BR, Madaiah N (1970) Quality of sausage emulsion prepared from mutton. J Food Sci 35(4): 383-385

Barbut S, Mittal GS (1992) Use of carrageenans and xanthan gum in reduced fat breakfast sausages. LWT- Food Sci Tech 25(6): 509–513

Bater B, Des Camps O, Maurer AJ (1992) Quality characteristics of hydrocolloid-added oven-roasted turkey breasts. J Food Sci 57(5): 1068–1070

Berry BW, Stiffler DM (1981) Effect of electrical stimulation, boiling temperature, formulation and rate of freezing on sensory, cooking, chemical, physical properties of ground beef patties. J Food Sci 46: 1103 – 1106

Biswas AK, Beura CK, Yadav AS, Pandey NK, Mendiratta SK, Kataria JM (2015) Influence of novel bioactive compounds from selected fruit by-products and plant materials on the quality and storability of microwave-assisted cooked poultry meat wafer during ambient temperature storage. LWT - Food Sci Tech 62: 727-733

Biswas AK, Chatli, MK, Sahoo, J (2016) Development of functional chicken nuggets with the incorporation of broken wheat and carrageenan. Ind J Poult Sci 51(1): 94-98.

Bloukas JG, Paneras ED, Papadima S (1997) Effect of carrageenan on processing and quality characteristics of low-fat frankfurters. J Muscle Foods 8(1): 63-83

Chatli MK (2001) Efficacy of different fat replacers on the processing quality and storage stability of low fat pork patties, Ph.D Thesis. IVRI Deemed University, Izatnagar

DeFreitas Z, Sebranek JG, Olson DG, Carr JM (1997) Carrageenan effects on salt soluble meat proteins in model system. J Food Sci 62(3): 539-543

Egbert WR, Huffman DL, Chen C, Dylewski DP (1991) Development of low fat ground beef. Food Technol 45(6): 64-73

Foegeding EA, Ramsey SR (1986) Effect of gums on low-fat meat batters. J Food Sci 51(1): 33– 46.

Foegeding EA, Ramsey SR (1987) Rheological and water holding properties of gelled meat batters containing iota carrageenan, kappa-carrageenan or xanthan gum. J Food Sci 52(3): 549–553.

Froehlich DA, Gullet EA, Usborne WR (1983) Effect of nitrite and salt on the colour, favour and overall acceptability of ham. J Food Sci 48: 152-154

Hsu SY, Chung HY (2001) Effects of K-carrageenan, salt, phosphates and fat on qualities of low fat emulsified meatballs. J Food Eng 47(2): 115–121

Huang C, Mikel LWB, Jones WR (1997) Carrageenan influences on the characteristics of restructured normal and pale, soft, and exudative hams. J Muscle Foods 8: 85–93

Huffman DL, Mikel WB, Egbert WR, Chen C, Dylewski DP (1991) Technology for low-fat ground beef. I: proc. Annual Reciprocal Meat Conference of the American Meat Science Association. 44: 73-78

Hughes E, Mullen AM, Troy DJ (1998) Effect of fat level, tapioca starch and whey protein on frankfurters formulated with 5 % and 12 % fat. Meat Sci 48:169–180

Indumathi J, Moorthy PRS, Sudhakara K, Reddy A, Jagadeesh B (2011) Development of low-fat chevon patties using sodium alginate as fat replacer. Tamilnadu J Vet Anim Sci 7(3): 167-173.

Keeton (1983) Effect of fat, sodium chloride and phosphate levels on the chemical and sensory properties of pork patties. J Food Sci 36: 261 – 276.

Kumar M, Sharma BD (2004) The storage stability and textural, physic-chemical and sensory quality of low fat ground pork patties with carrageenan as fat replacer. Int J Food Sci Technol 39: 31-42.

Lin KW, Keeton JT (1998) Textural and physic-chemical properties of low fat, precooked ground beef patties containing carrageenan and sodium alginate. J Food Sci 64(4): 571.

Matanjun P, Suhaila M, Noordin MM, Kharidah M, Ming CH (2008) Antioxidant activities and phenolic content of eight species of seaweeds from north Borneo. J Appl Phycol 20: 367-373.

Mittal GS, Barbut, S (1994) Effect of fat reduction on frankfurters physical and sensory characteristics. Food Res Int 27: 425-431.

Morin LA, Temelli F, McMullen L (2002) Physical and sensory characteristics of reduced-fat breakfast sausages formulated withbarley b-glucan. J Food Sci 67:2391–2396

Naruka SS (2005) Physico-chemical, microbiological and sensory attributes of low fat pork nuggets prepared using carrageenan guargum and gum of tragacanth as fat replacers. M. V. Sc. Thesis .GBPUAT, Pantnagar, Uttarakhand, India

Nayak NK, Pathak V (2016) Development and quality assessment of carrageenan incorporatedlow fat chevon patties. J Food Sci Technol 53(9): 3477–3484

Necas J, Bartosikova L (2013) Carrageenan: a review. Vet Med 58 (4): 187–205

Pannin J, Polic M, Dordevic M (1974) The use of carrageenan in the manufacture of semi-perishable canned meat products. Technologija Mesa 15(3): 82-84

Pietrasik Z, Jarmoluk A (2003) Effect of sodium caseinate and K-carrageenanon binding and textural properties of pork muscle gels enhanced by microbial transglutaminase addition. Food Res Int 36: 285–294

Prabhu G, Sebranek, J (1997) Quality characteristics of ham formulated with modified cornstarch and kappa-carrageenan. J Food Sci 62: 198–202

Shand P, Sofos JN, Schmidt GR (1994) Kappa-carrageenan, sodium chloride and temperature affect yield and texture of structured beef rolls. J Food Sci 59: 282–287

Snedecor GW, Cochran WG, (1994) Statistical Methods. 8th edition, New Delhi. Oxford and IBH Publishing.

Song FL, Gan RY, Zhang Y, Xiao Q, Kuang L, Li HB (2010) Total phenolic contents and antioxidant capacities of selected chinese medicinal plants. Int J Mol Sci 11: 2362–2372.

Tatiya AU, Tapadiya GG, Kotecha S, Surana SJ (2011) Effect of solvents on total phenolics, antioxidantand antimicrobial properties of Bridelia retusa Spreng. Stem bark. Indian J Nat Prod Res 2(4): 442-447.

Trout ES, Hunt MC, Johson DE, Clans JR, Castner CL, Kroff DH (1992) Characteristics of low fat ground beef containing texture modifying ingredients. J Food Sci 57: 19–24

Tukey J (1949) Comparing individual means in the analysis of variance. Biometrics 5(2): 99-114

Van de Velde F, Lourenco ND, Pinheiro HM, Bakkerd M (2002) Carrageenan: a food-grade and biocompatible support for immobilisation techniques. Adv Synth Catal 344: 815–835

Wallingford L, Labuza, TP (1983) Evaluation of the water binding properties of food hydrocolloids by physico-chemical methods and in a low fat meat emulsion. J Food Sci 48: l-5.