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Effect of Super-Chilling on the Shelf Life of Chicken Nuggets

P.C. Kanle, K.S. Rathod and R.K. Ambadkar*

Dept. Livestock Products Technology, Nagpur Veterinary College, Seminary Hills, Nagpur

ABSTRACT

This study was conducted to assess the composition, physicochemical, microbiological and sensory quality of aerobically packaged chicken nuggets stored at two different superchilling temperature (-2 ±0.5ºC and -0.5±0.5ºC) and compare with storage under frozen (-20±1ºC) and chilling (4±1ºC) temperature for 35 days. The products stored at chilling (4±1ºC) temperature spoiled within 28 days. The moisture content of super-chilled samples was significantly lower than frozen sample and higher than chilled samples. However there was no significant variation in the fat content of the product stored at different temperatures. There was a significant increase in pH of chilled samples than super-chilled with progress in the storage period. The TBA and tyrosine values of the superchilled samples were significantly lower than chilled samples during the storage. Super-chilled nuggets showed significantly lower TPC and psychrophillic counts as compared to chilled nuggets. Sensory evaluation also revealed significantly high scores for super-chilled product than chilled nuggets indicating usefulness of super-chilling temperature for extension of shelf life.

Keywords: *Aerobic Packaging, Chicken Nuggets, Quality analysis, Shelf Life, Super-chilling*

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INTRODUCTION

Muscle food plays major role in the diet of non-vegetarian consumers. With increasing population and their expectation for fresh and healthy foods, it is essential to preserve the freshness of foods. This will in turn, help to increase its shelf life and maintain texture, flavor and nutritive value. However a main challenge is to maintain a stable and sufficiently low temperature which is practically difficult in fresh foods during distribution and storage (Aune, 2003).

Meat is highly perishable food item due to its biological composition. The shelf life of refrigerated meat is limited, primarily due to microbial activities (Duun, 2008; Fernández *et al.* 2010; Lambert *et al.* 1991). Temperature is one of the most important parameters affecting the growth of microorganisms (Borch *et al.* 1996; Bréand *et al.* 1997, 1999). To minimize the growth of spoilage and pathogenic bacteria, the storage temperature must be reduced as much as possible, without affecting the product quality.

Super-chilling is a method that can be used to maintain foods at a low temperature where in a minor part of its water content is frozen (Magnussen *et al.* 2008). Super-chilling implies temperatures to the borderline between chilling and freezing. At this temperature, microbial activity is reduced and most bacteria are unable to grow. During super-chilling, the temperature of the product is lowered, often 1–2°C, below the initial freezing point of the product. After initial surface freezing, the ice distribution equilibrates and the product obtains a uniform temperature at which it is maintained during storage and distribution (Magnussen *et al*, 2008). This has been effectively used for seafood (Olafsdottir *et al.* 2006; Beaufort *et al.* 2009) and there is now increasing interest in application of this process for extension of storage life of other meats (Schubring 2009). Since research on utilization of super-chilling technique on processed meat products is limited, the present study was conducted to evaluate the quality of chicken nuggets stored under super-chilling temperature at aerobic condition.

MATERIALS AND METHODS

The chilled (2ºC) boneless chicken meat from halal slaughtered poultry was procured from local shop and packaged in LDPE pouches, kept at refrigeration (4±1ºC) temperature overnight and subsequently used for product formulation.

Deboned chilled meat was cut into small pieces and minced in meat mincer (Stadler Corporation, Mumbai). Salt, sodium nitrite and sodium tripolyphosphate were added in to the minced meat and chopped in bowl chopper (Stadler Corporation, Mumbai) for 2 min, with addition of ice flakes (1 min.), vegetable oil (1 min.), whole egg liquid (2 min.) refined soy flour, condiments and spice mix (2 min.) to obtain an emulsion. Chicken nuggets were prepared from emulsion according to the method of Nag (1998) with slight modifications. The moulds containing emulsion were kept in a steam cooker and cooked for 35 min without pressure. Cooked loaf was cooled to room temperature and cut into size of nuggets (4 x 1.5 x 1.5 cm) which were subsequently packaged in LDPE pouches and placed in freezer at -20±1°C for 2 hrs to bring down the temperature. Then the samples were stored under super-chilling (-2 ± 0.5°C and -0.5 ± 0.5°C), chilling (4±1ºC) and frozen (-20±1ºC) conditions.

The product was evaluated for proximate composition, pH, TBA number, tyrosine value and microbiological quality (total plate count and psychrophilic count) as well as sensory quality at an interval of 7 days during the study period of 35 days. The moisture (%), fat (%) and protein (%) content of chicken nuggets were determined as per the method of AOAC (1995). Thiobarbituric acid number of chicken nuggets were determined as per the method suggested by Strange *et. al.,* (1977) with slight modifications. Tyrosine value of chicken nuggets were estimated by the extraction method of strange *et al* (1977). The microbiological

*Corresponding author E-mail address: rk_ambadkar@rediffmail.com
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quality of chicken nuggets was assessed on the basis of total plate count (TPC) and psychrophilic count (PC) as per the procedure of APHA (1984).

The nuggets were subjected for sensory evaluation to assess the appearance, flavor, texture, juiciness, and overall acceptability by an experienced panel members using 8 point descriptive scale (Keeton *et al.* 1983) and the data generated was analyzed by Analysis of Variance following the procedure described by Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

The changes observed in physico-chemical parameters of the aerobically packed chicken nuggets in LDPE pouches stored under four different temperatures viz., -2 ± 0.5ºC (T1), -0.5± 0.5ºC (T2), 4±1ºC (T3) and -20±1ºC (T4) at 7 days interval are represented in Table 1.

There was a significant reduction in moisture content of chilled sample (62.83± 0.60) than both super-chilled and frozen samples on 21st day of storage. Moreover, moisture percent of super-chilled samples T_1 (63.23± 0.95) and T2 (64.08± 0.22) were also significantly lower than frozen (64.15± 0.29) sample. At the end of storage on 35th day, the moisture in T_1 was found to be significantly low as compared to T_2 and frozen samples. This reduction in moisture content might be due to the decrease in pH (Huff-Lonergan and Lonergan 2005) during storage. Rathod (2017) also reported significant reduction in moisture of frozen (-20±1ºC) as well as superchilled (-1.5 to -2.5ºC) chicken samples throughout storage of 20 days under aerobic packaging. During storage, no

Table 1: Physico-chemical changes in aerobically packed super-chilled chicken nuggets during storage

Treatment	Storage period (Days)					
	0	7	14	21	28	35
			Moisture (%)			
(-2 ± 0.5ºC)	64.55± 0.19	64.39± 0.30	64.25± 0.20	63.23±0.95^{ad}	61.69± 0.73^{a}	60.70±0.66^{a}
(-0.5 ± 0.5ºC)	64.75± 0.27	64.53± 0.28	64.39± 0.35	64.08±0.22^{ab}	63.77±0.26^{bc}	62.66±0.43^{bc}
(4 ± 1ºC)	64.48± 0.15	64.22± 0.15	64.07±0.32	62.83± 0.60^{c}	Spoiled	--
(-20± 1ºC)	64.91± 0.22	64.71± 0.42	64.50± 0.26	64.15±0.29^{bd}	64.04± 0.15^{c}	63.03±0.41^{c}
			Protein (%)			
(-2 ± 0.5ºC)	17.85± 0.28	17.74± 0.11	17.75± 0.32	17.65± 0.23	17.13± 0.43	17.43±0.34
(-0.5 ± 0.5ºC)	17.90± 0.21	17.76± 0.26	17.65± 0.37	17.52± 0.26	17.49± 0.33	17.39±0.36
(4 ± 1ºC)	17.77± 0.14	17.87± 0.22	17.74± 0.17	17.70± 0.16	Spoiled	--
(-20± 1ºC)	17.88± 0.20	17.77± 0.11	17.09± 0.16	17.73± 0.25	17.70± 0.18	17.60±0.28
			Fat (%)			
(-2 ± 0.5ºC)	13.65± 0.17	13.64± 0.13	13.62± 0.17	13.49± 0.13	13.42±0.17	13.46± 0.13
T_2 (-0.5 ± 0.5ºC)	13.65± 0.32	13.61± 0.26	13.62± 0.32	13.57± 0.26	13.58±0.32	13.58± 0.26
T_3 (4 ± 1ºC)	13.62± 0.14	13.60± 0.21	13.55± 0.14	13.56± 0.21	Spoiled	--
T_4 (-20± 1ºC)	13.65± 0.16	13.66± 0.14	13.66± 0.16	13.65± 0.14	13.65±0.16	13.64± 0.14
			pH			
T_1 (-2 ± 0.5ºC)	6.29± 0.02^{a}	6.26± 0.03^{ac}	6.28± 0.02^{ad}	6.30± 0.03^{a}	6.32± 0.02^{a}	6.34± 0.03^{a}
T_2 (-0.5 ± 0.5ºC)	6.30± 0.02^{ab}	6.27± 0.02^{a}	6.30±0.02^{b}	6.31± 0.02^{a}	6.33± 0.02^{a}	6.36± 0.02^{b}
T_3 (4 ± 1ºC)	6.31± 0.03^{b}	6.32± 0.02^{b}	6.35± 0.0^{3c}	6.39± 0.02^{b}	Spoiled	--
T_4 (-20± 1ºC)	6.27± 0.02^{c}	6.25± 0.01^{c}	6.27± 0.02^{d}	6.28± 0.01^{c}	6.28± 0.02^{b}	6.29± 0.01^{c}
			TBA (mg malanoaldehyde/kg)			
T_1 (-2 ± 0.5ºC)	0.29± 0.02	0.30± 0.03^{a}	0.32±0.02^{a}	0.39± 0.03^{a}	0.51± 0.02^{a}	0.61± 0.03^{a}
T_2 (-0.5 ± 0.5ºC)	0.30± 0.02	0.31±0.01^{a}	0.42±0.02^{b}	0.44±0.01^{b}	0.61±0.02^{b}	0.63± 0.01^{a}
T_3 (4 ± 1ºC)	0.33± 0.01	0.34± 0.03^{a}	0.65±0.01^{c}	0.67±0.03^{c}	Spoiled	--
T_4 (-20± 1ºC)	0.25± 0.01	0.22±0.03^{b}	0.22±0.01^{d}	0.28±0.03^{d}	0.51± 0.01^{a}	0.58± 0.03^{b}
			Tyrosine (mg/100g)			
T_1 (-2 ± 0.5ºC)	17.29± 0.50	18.08±0.65^{ac}	18.33± 0.50^{a}	20.71± 0.65^{a}	22.92±0.50^{a}	23.46± 0.65^{a}
T_2 (-0.5 ± 0.5ºC)	17.42± 0.88	18.17± 0.20^{a}	18.75± 0.88^{a}	20.79± 0.20^{a}	23.42± 0.88^{a}	23.88± 0.20^{a}
T_3 (4 ± 1ºC)	18.08± 0.65	20.71± 0.29^{b}	22.92± 0.65^{b}	26.03± 0.29^{b}	Spoiled	--
T_4 (-20± 1ºC)	17.29± 0.50	17.63± 0.65^{c}	18.17± 0.50^{a}	18.08± 0.65^{c}	19.88± 0.50^{b}	20.92± 0.65^{b}

Means ± S.E (n=6) with different superscripts in a column differ significantly (P <0.05).

significant variations in the protein and fat content of the product were observed.

The pH indicated significant difference between super-chilled, chilled and frozen samples on day 21 of storage. The pH of all the samples increased during the storage period and was significantly higher in chilled sample (6.39± 0.02) than both super-chilled T1 (6.30± 0.03), T_2 (6.31± 0.02) and frozen (6.28± 0.01) samples on 21st day of storage. However, at the end of storage, super-chilled samples showed significant increase in pH than frozen samples. This consistent increase in pH during storage could be due to liberation of protein metabolites by bacterial enzymes. The results are in support of Kumar and Tanwar (2011) and Ozer and Saricoban (2010) who recorded gradual increase in pH of chicken patties during storage.

The TBA values of chicken nuggets, irrespective of temperature, increased significantly ($p<0.05$) from 14th day of the storage. TBA values of different treatments on day 21 were 0.39±0.03 (T_1), 0.44±0.01 (T_2), 0.67±0.03 (T_3), 0.28±0.03(T_4) indicating significant increase of TBA in chilled followed by super-chilled samples. At the end of storage, there was no significant difference in TBA of both super-chilled samples although TBA value increased significantly higher than frozen samples. The increase in TBA value throughout the storage period might be due to the lipid oxidation attributed to oxygen permeability of packaging material (Brewer *et al.,* 1992). The results are in support of Naveena *et al.* (2008) and Devatkal *et al.* (2011) in chicken patties and chevon patties respectively.

Table 2: Microbiological changes in aerobically packed super-chilled chicken nuggets during storage

Treatment	Storage period (Days)					
	0	7	14	21	28	35
			TPC (Log_{10}cfu/g)			
(-2 ± 0.5°C)	0.50± 0.50^a	3.56± 0.06^a	3.86± 0.05^a	4.11±0.07^a	4.48± 0.07	4.58± 0.04
(-0.5 ± 0.5°C)	0.50± 0.50^a	3.73± 0.07^a	3.98± 0.05^a	4.06±0.09^a	4.49± 0.06	4.63± 0.04
(4 ± 1°C)	3.46± 0.11^b	4.64± 0.04^b	4.76± 0.03^b	5.03± 0.06^b	Spoiled	--
(-20± 1°C)	0.00± 0.00^a	2.83± 0.57^c	3.80± 0.05^a	3.80±0.08^a	4.02± 0.06	4.36± 0.13
			PPC (Log_{10}cfu/g)			
(-2 ± 0.5°C)	NIL	NIL	NIL	2.60±0.52^a	3.46±0.11^a	3.69± 0.03
(-0.5 ± 0.5°C)	NIL	NIL	NIL	2.73±0.55^a	3.58± 0.08^a	3.72± 0.04
(4 ± 1°C)	NIL	NIL	3.21± 0.11	3.76± 0.08^b	Spoiled	--
(-20± 1°C)	NIL	NIL	0.00± 0.00	0.00±0.00^c	2.65± 0.53^b	3.45± 0.11

Means ± S.E with different superscripts in a column differ significantly ($p<0.05$).

There was significant increase in tyrosine value of chilled as well as in super-chilled samples. However, tyrosine value of both super-chilled (T_1- 20.71±0.65 and T_2 – 20.79± 0.20) samples was significantly lower than chilled (26.03±0.29) sample on day 21. Similarly, there was significant increase in tyrosine value in super-chilled samples than frozen samples on day 35. The results were in support of Suradkar (2008) who recorded inclining trend in tyrosine value during refrigerated storage of chicken nuggets. The increase in tyrosine value might be due to protein degradation reactions initiated by meat spoilage bacteria and endogenous enzymes (Muela *et al.,* 2010).

The microbiological analysis (Table 2) indicated that there was gradual increase in total plate count (TPC) during entire storage period of 35 days in all treated samples. However, super-chilled samples showed significantly lower TPC than chilled sample on day 21. The results were in support of Suradkar (2008) who recorded similar results during refrigerated storage of chicken nuggets. At the end of storage (day 35) there was no significant variations in TPC of chicken nuggets during storage at 4+1 0C.

No Psychrophillics counts were observed in super-chilled and frozen samples upto 14 days of storage. Later during the storage PPC of super-chilled samples were significantly higher than frozen sample which might be due to the increased enzymatic activity of psychrotrophs at super-chilling temperature contributing deterioration (Kandeepan and Biswas 2007). Similar results were reported by Rathod (2017) in super-chilled chicken breast fillet stored under aerobic condition.

CONCLUSION

On the basis of the present findings, it is concluded that, the shelf life of aerobically packed chicken nuggets could be extended upto 35 days under superchilling (-0.5 ± 0.5°C and -2 ± 0.5°C) conditions without adverse effect on the quality as compared to 21 days shelf-life under chilled condition.

COMPETING INTERESTS: The authors have no known competing interests either financial or personal between themselves and others that might bias the work.

ETHICS STATEMENT: Not Applicable

Table 3: Sensory changes in aerobically packed super-chilled chicken nuggets during storage

Treatment	Storage period (Days)					
	0	7	14	21	28	35
			Appearance			
T_1 (-2 ± 0.5ºC)	7.19±0.13	7.11±0.08^{ab}	7.28±0.10^{a}	6.86± 0.13^{a}	6.75± 0.09	6.31±0.08^{a}
T_2 (-0.5 ± 0.5ºC)	7.22± 0.11	7.11±0.08^{ab}	7.22±0.10^{a}	6.81± 0.15^{a}	6.83± 0.11	6.28±0.08^{a}
T_3 (4 ± 1ºC)	7.25± 0.12	6.89± 0.11^{a}	6.86± 0.16^{b}	6.33± 0.18^{b}	Spoiled	--
T_4(-20± 1ºC)	7.33± 0.11	7.33± 0.14^{b}	7.42±0.10^{a}	7.06± 0.16^{a}	7.03± 0.11	6.89± 0.06^{b}
			Flavour			
T_1 (-2 ± 0.5ºC)	7.33±0.11^{a}	6.97± 0.08^{a}	6.86±0.11^{a}	6.43± 0.14^{a}	6.14±0.13^{a}	6.06± 0.11^{a}
T_2 (-0.5 ± 0.5ºC)	7.06± 0.09^{a}	6.94± 0.11^{a}	6.83±0.09^{a}	6.61± 0.18^{a}	6.53±0.14^{b}	6.22± 0.13^{a}
T_3 (4 ± 1ºC)	6.92± 0.07^{b}	6.67± 0.09^{b}	6.14±0.14^{b}	5.56± 0.17^{b}	Spoiled	--
T_4 (-20± 1ºC)	7.56± 0.10^{a}	7.33± 0.10^{c}	7.28±0.07^{c}	7.08± 0.10^{c}	7.17± 0.11^{c}	7.00± 0.04^{b}
			Juiciness			
T_1 (-2 ± 0.5ºC)	7.25±0.15^{ac}	6.89±0.09^{ab}	6.87±0.12^{a}	6.50± 0.13^{a}	6.20± 0.15^{a}	6.14± 0.11^{a}
T_2 (-0.5 ± 0.5ºC)	7.08± 0.09^{a}	7.14± 0.15^{a}	6.86±0.11^{a}	6.67± 0.17^{a}	6.50± 0.11^{a}	6.22± 0.14^{a}
T_3 (4 ± 1ºC)	6.92± 0.08^{b}	6.64± 0.12^{b}	6.25± 0.15^{b}	5.69±0.16^{+}	Spoiled	--
T_4 (-20± 1ºC)	7.44± 0.10^{c}	7.39± 0.10^{c}	7.33±0.08^{c}	7.19± 0.11^{b}	7.06± 0.11^{b}	6.94± 0.08^{b}
			Texture			
(-2 ± 0.5ºC)	7.14± 0.14	6.89± 0.09	7.00± 0.11	6.47± 0.17^{a}	6.17± 0.15^{a}	5.92± 0.11^{a}
(-0.5 ± 0.5ºC)	6.97± 0.10	7.00± 0.08	6.94± 0.09	6.72± 0.14^{a}	6.39± 0.12^{a}	6.17± 0.09^{a}
(4 ± 1ºC)	6.94± 0.07	6.83± 0.08	6.78± 0.12	6.00± 0.17^{b}	Spoiled	--
(-20± 1ºC)	7.08± 0.08	7.00± 0.08	7.17± 0.07	7.06± 0.08^{b}	6.89± 0.13^{b}	6.89± 0.09^{b}
			Overall palatability			
(-2 ± 0.5ºC)	7.25± 0.13^{ab}	7.00±0.08^{ab}	6.86± 0.11^{a}	6.61± 0.14^{a}	6.17± 0.12^{a}	5.83± 0.12^{a}
(-0.5 ±0.5ºC)	7.00± 0.13^{a}	7.14± 0.13^{a}	6.97± 0.09^{a}	6.69± 0.18^{a}	6.50± 0.13^{b}	6.11± 0.13^{a}
(4 ± 1ºC)	7.06± 0.07^{a}	6.75± 0.10^{b}	6.33± 0.10^{b}	5.67± 0.17^{b}	Spoiled	--
(-20± 1ºC)	7.36± 0.10^{b}	7.25± 0.09^{a}	7.36± 0.07^{c}	7.22± 0.09^{c}	7.08± 0.09^{c}	7.06± 0.04^{b}

Means ± S.E with different superscripts in a column differ significantly ($p<0.05$) (n=18)

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