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Full Length Research Paper

Fish product quality evaluation based on temperature monitoring in cold chain

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As one kind of perishable food, fish product is at risk of suffering various damages during cold chain and temperature is the most important factor to affect the product quality. This research work on frozen tilapia fillet was aimed at evaluating the fish product quality and predict shelf-life through monitoring temperature change inside the refrigerated vehicle with the radio frequency identification (RFID) technology and analyze the effect of temperature experience and profile on quality. The contrast experiment under different temperature condition was designed, namely: -18°C stable, -18°C fluctuated with ±2°C and room temperature. Temperature data were collected by RFID record at different points in the vehicle, and then product quality of three corresponding groups was evaluated according to sensory analysis and total volatile base-nitrogen (TVB-N) value. The result shows that product temperature in different point has no significant difference (P > 0.05) and product shelf- life of the same group also has a little difference between sensory analysis and TVB-N value. Shelf-life of product along with temperature fluctuated within 0.5°C was two months longer than within 2.0°C, meanwhile, the rate of quality deterioration is an accelerated process with the passage of storage time.

Key words: Frozen tilapia fillet, temperature, cold chain, shelf-life, total volatile base-nitrogen, sensory evaluation.

INTRODUCTION

Consumers around the world increased consumption of fish and fish product in recent years due to recognition of their nutritional value. But as one kind of perishable and short shelf-life goods, fishes are easy to deteriorate and the process is accelerated with increasing temperature owing to a number of factors such as microbial metabolism, oxidative reaction and enzymatic activity (Gram and Huss, 1996; Koutsoumanis and Nychas, 2000; Sivertsvik et al., 2002; Giannini et al., 2007; Makarios-Laham and Lee, 1993). Consequently, fish economic value and use value was seriously affected. The cold chain management (CCM) has become crucial, challenging and important to keep fish product safety due to a high number of product variants, strict traceability requirements from the customer and the need for temperature control in the supply chain (Mikko, 2003; Barroso et al, 1998; Nielsen and Jorqensen, 2004; Laguerre and Flick, 2007; Tsironi et al, 2008).

The key focus of cold chain management is paid to integrate the sensitive temperature management and shelf-life evaluation to provide the accurate and reliable information about the rest shelf-life (Shimoni et al., 2001).

Time-temperature-tolerance theory (TTT) illustrates that food quality decrease is irreversible and accumulated resulting from time-temperature experience. Chemic indicators and sensory evaluation reflect that the product quality is affected by temperature fluctuation. Literature show that many experiments explore fish product quality and reasonable shelf-life integrated total volatile base-

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Abbreviations: RFID, Refrigerated vehicle with the radio frequency identification; **TVB-N,** total volatile base-nitrogen; **CCM,** cold chain management; **TTT,** time-temperature-tolerance theory.

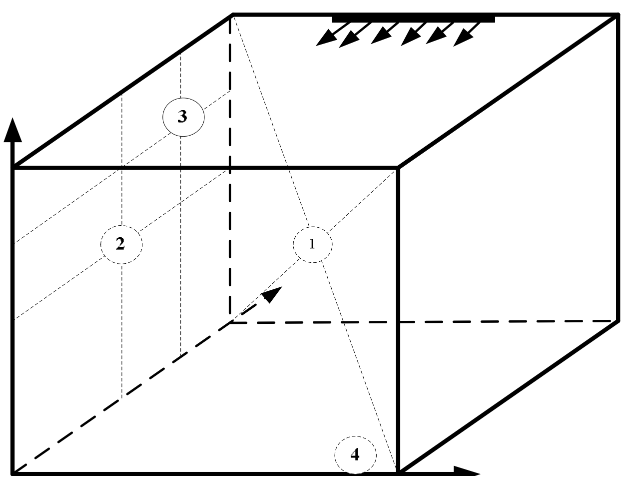

Figure 1. The RFID recorder placements of tilapia fillet samples in the refrigerated vehicle.

nitrogen (TVB-N), pH, trimethylamine, peroxide values (Fagan et al., 2003; Arannilewa et al., 2005; Tsironi et al., 2008) with sensory analysis (Tejada et al., 2006) under discrete temperature condition. However, these researches did not reveal quality change on time along with continuous temperature fluctuation.

It is clear, therefore, that an effective integration between temperature monitoring and management and quality evaluation helps to solve the challenge in cold chain management for short shelf-life product. Efficient capture of data in cold chain helps to improve the quality evaluation efficiency. There are two methods of temperature monitoring. One is thermometers or compact temperature loggers installed in vehicle and warehouse. Each logger should be connected physically to computer to manage temperature data, and then the data collection becomes a manual operation. The other is time temperature integrators (TTI), which can reflect temperature profile through color change, so product quality can be judged (Taoukis and Labuza, 2003; Giannakouroua et al, 2005).

However, implementation of traditional temperature management system is of high management costs, has unease of introduction and data collection and reduce accuracy of reading rate, particularly in successive handling situations and in difficult environments. The new technology, RFID (Radio frequency identification) temperature recorder and reading device (Jedermann et al., 2009) was used to monitor temperature fluctuation due to the fact that it can measure and record time-temperature information and perform temperature management across multiple businesses by starting/stopping the measurement and collecting the data independently, without requiring other businesses to perform the work required for the temperature management.

This paper aims to monitor continuous temperature fluctuation of frozen tilapia fillet by RFID temperature record during the cold chain, to compare product temperature fluctuation in different location by statistical analysis, then to analyze and discuss continuous temperature fluctuation impact on frozen tilapia fillet quality based on TVB-N experiment and sensory evaluation.

MATERIALS AND METHODS

Sample preparation and experiment design

Frozen tilapia fillet was selected as research object in the experiment, taking into account: 1) Tilapia has already been noted as a highly suitable species for low cost aquaculture worldwide as they can thrive on a lower protein diet and has the potential to be a more sustainable source of protein with fewer ambient impacts; and with its form, white flesh and mild taste could be a suitable substitute for wild whitefish stocks such as cod and others which are frequently exposed in the media as over fished (http://www.farming4profit.co.uk). 2) China is the largest tilapia producer in the world, keeping a strong growth in export and leading the growth rate for several years. The growth in tilapia output is driven by strong domestic demand as well as exports. Furthermore, frozen fillet is the main export variety of tilapia product.

All the tilapia fillet samples were selected from a storehouse whose temperature was about -18℃ in Beijing XXX Company, China, then divided into three groups as contrast experiment. One group was kept in the fridge at -18℃ stable, another group was kept in refrigerated vehicle for 8 h transportation at -18℃ and the third were kept in the vehicle without refrigeration for 8 h.

After transportation, the three group samples were put into a fridge kept at -18℃, and then sensory evaluation and TVB-N experiment were implemented to calculate the tilapia fillet shelf-life. Comparing with three group samples, temperature history and the fluctuation impact on shelf-life was analyzed.

Temperature collection and monitoring scheme

Temperature fluctuation monitoring was achieved by attaching temperature recorder in different locations of refrigerated vehicle. The ML-T110 RFID temperature recorder was adopted with advantage of working in the low temperature and high humidity. Its easurement is in range of -40 - 85℃, at the accuracy of 0.1℃, and the data is retrievable by RFID reader automatically without other device.

The RFID temperature recorder working parameter was set up as frequency of ten minutes from 9:00 am to 17:00 pm. The recorder was conjoint to tilapia fillet to collect sample temperature data during the transportation. Figure 1 illustrates the settlement placements in the vehicle.

Another four RFID temperature recorders were attached to the inner wall of the refrigerated vehicle to record ambient temperature data. Figure 2 describes RFID recorder positions.

Quality evaluation and Shelf-life modeling

Sensory analysis

The sensory quality of tilapia fillet samples were evaluated directly after transportation and at 4th, 7th, 9th, 11th, 13th and 14th month of frozen storage at -18℃, according to five-point method. Tilapia fillet quality was scored on a 1 - 5 scale (1- very bad, 2- bad, 3- good, 4- very good, 5- excellent) from a team, which consisted of five judges fulfilling sensory evaluation. Samples were evaluated in terms of visual appearance, texture, taste and smell. Every parameter

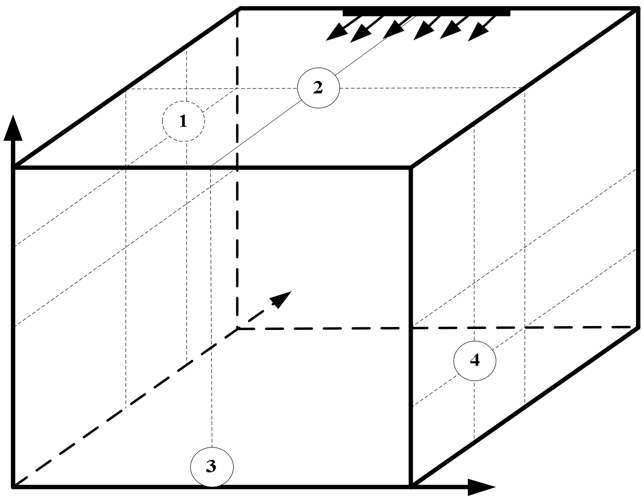

Figure 2. Four points of temperature recorders inside the refrigerated vehicle.

value must be greater than or equal 3. If one parameter is less than 3, it shows that the tilapia fillet has expired.

TVB-N

The deterioration of tilapia fillet was evaluated through the determination of TVB-N value referring to the method of China Standard (GB) SC/T 3032 (2007), and the frequency of measurement was the same as sensory evaluation. If the measured value exceeds the security limit 30 mg/100 g, referring to GB2733 (2005), then further analysis would be terminated.

The shelf-life indicates the product remaining alive until a specific threshold is exceeded. These thresholds could be constitutive of consumer acceptance, bacterial limit, color, etc (Tijskens and Polderdijk, 1996; Jedermann et al., 2009). This study adopts the sensory analysis score and TVB-N value as the standard to identify the tilapia fillet quality.

Data analysis

Statistical analysis system (SAS, 2002) software was adopted to analyze the temperature diversity between different locations inside the refrigerated vehicle, based on analysis of variance (ANOVA). The significance was accepted at $P>0.05$.

RESULTS AND DISCUSSION

Temperature fluctuation inside the refrigerated vehicle

Figure 3 illustrates the temperature fluctuation in the different positions. Table 1 shows the result of temperature diversity between four points at the same time based on SAS software.

At first, all the sample temperature was below -18℃, and product temperature presented a slowly increased trend with several fluctuation phases during the whole transportation. The maximum temperature span, 0.47℃, appears at 2.7 h. The sample 1 temperature fluctuates weakly among four samples due to the fact that it is located in the center of products; meanwhile, sample 3 fluctuates significantly for it is located at the door of the vehicle and it exchanges heat with environment while the door opens.

Figure 4 shows that ambient temperature inside the vehicle fluctuated sharply. Several wave crests appears during the whole transportation. The minimum temperature is -18.6℃ appearing at half hour later, and the maximum is 16.8℃ after six hours.

The temperature has a declining trend (Figure 4), because the vehicle is in a refrigerating stage, and then the fluctuation lasts near four hours. The highest wave crest appears 6.5 h later, as the vehicle door opens and the tilapia fillets are unloaded except samples, heat exchanges between internal and external environment. Temperature drops rapidly after tilapia fillets are unloaded, rising slowly at the end of transportation. Temperature of point 2 located at exit of cold air fluctuated drastically the most.

Sensory evaluation

Table 2 shows the sensory evaluation score. After transportation, the quality of both groups 1 and 2 were consistently excellent, with score 5.0. The quality of group 3 decreased obviously.

The visual appearance score for groups 1 and 2 began at 5.0. Along with the passage of storage time, the deterioration rate of group 2 was a little faster than group 1. The deterioration rate of group 3 fillet was the fastest. Texture score for groups 1 and 2 fillet indicated that, with respect to other three sensory quality indicators, the deterioration rate was the slowest, being in the range of 3.2 -3.6 and 3.3 -3.5 after 13 and 9 months, respectively. The group 3 fillet score was 2.3 after 9 months, under the threshold, so the longest storage time was recommended as 7 months.

Taste and smell score also indicated that with the passage of storage time, the quality decreased, further more, the rate of quality deteriorated with an accelerated speed. The quality of group 3 fillet decreased rapidly the most.

From the above analysis, it shows that low temperature transportation has a positive effect on tilapia fillet quality, especially visual appearance; the most probability is that in ice crystals around tilapia fillet thawed in non-refrigeration environment.

TVB-N measurement

Figure 5 illustrates TVB-N value change trend, similar with the previous research (Koutsoumanis and Nychas, 2000). At the beginning of storage, TVB-N value was

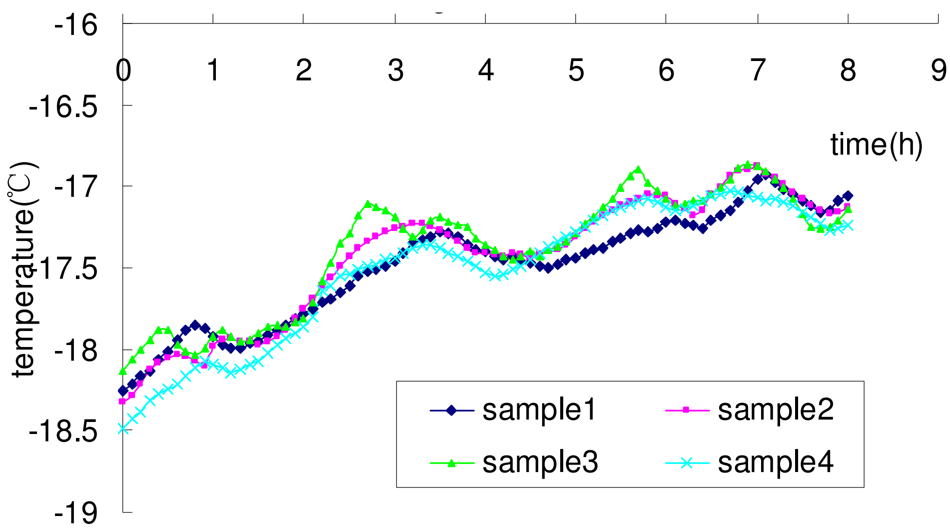

Figure 3. Temperature fluctuation of frozen tilapia samples in refrigerated vehicle.

Table 1. The result of product temperature diversity.

The ANOVA Procedure					
Source	**DF**	**Anova SS**	**Mean Square**	**F**	**Pr > F**
Sample	3	0.0278849	0.0139425	0.28	0.7577

Given that Pr > F = 0.7577 was more than 0.05, the diversity was not significant.

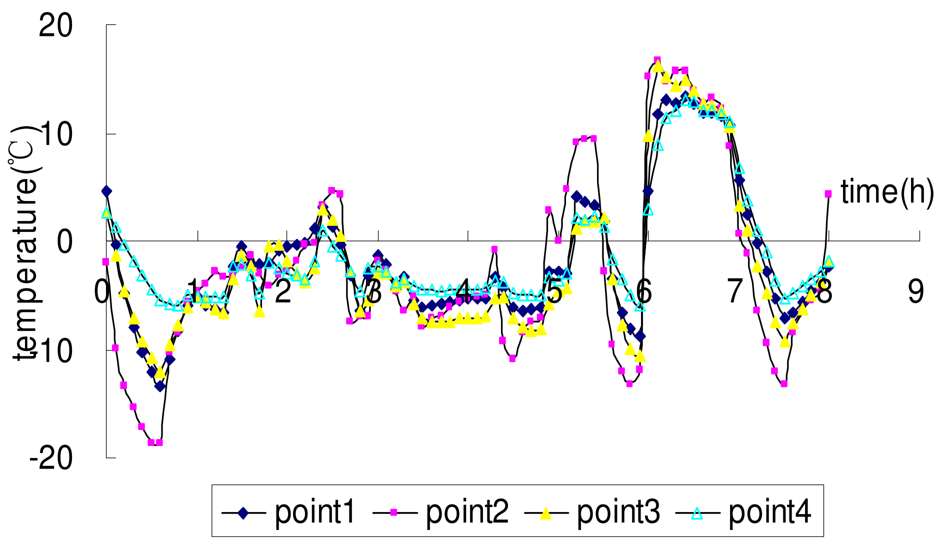

Figure 4. Ambient temperature fluctuation inside the refrigerated vehicle.

nearly equal among three group tilapia fillet samples. Along with storage time passed, TVB-N value increased more and more quickly (Manju et al., 2007), and the speed of group 3 fillet was more rapid than the others. At the 9th month, TVB-N value of group 3 went up to 30 mg/100 g, which was in the acceptable limit. However, the others reached 15 mg/100 g and 17 mg/100 g, respectively, for group 1 and group 2. At 13th month, TVB-N value of group 1 fillet achieved 27 mg/100 g, nearly at the threshold; group 2 achieved 33 mg/100 g beyond the acceptable limit, so the shelf-life was recommended as 11 months.

Table 2. Sensory evaluation of tilapia fillets with the 5-point method.

Quality indicator	Time of storage (month)	Kind of process		
		Group 1	Group 2	Group 3
Visual appearance	0	5.0±0.0	5.0±0.0	4.1±0.1
	4	4.8±0.1	4.7±0.1	3.8±0.2
	7	4.5±0.1	4.2±0.1	3.1±0.1
	9	4.0±0.2	3.6±0.2	2.5±0.1
	11	3.6±0.1	2.9±0.1	…
	13	3.1±0.1	2.3±0.2	…
	14	2.8±0.2	…	…
Texture	0	5.0±0.0	5.0±0.0	4.3±0.1
	4	4.8±0.1	4.5±0.1	3.6±0.2
	7	4.6±0.1	4.0±0.2	3.0±0.1
	9	4.3±0.1	3.4±0.1	2.3±0.1
	11	3.8±0.1	2.9±0.1	…
	13	3.4±0.2	…	…
	14	3.0±0.2	…	…
Taste	0	5.0±0.0	5.0±0.0	4.6±0.1
	4	4.9±0.1	4.6±0.1	4.1±0.2
	7	4.6±0.0	4.0±0.1	3.3±0.1
	9	4.2±0.1	3.4±0.1	2.7±0.1
	11	3.6±0.1	2.7±0.2	…
	13	3.1±0.2	…	…
	14	2.5±0.1	…	…
Smell	0	5.0±0.0	4.9±0.1	4.5±0.1
	4	4.7±0.1	4.6±0.1	4.3±0.1
	7	4.3±0.2	4.1±0.2	3.7±0.2
	9	3.8±0.1	3.5±0.1	3.0±0.1
	11	3.5±0.1	2.9±0.2	…
	13	2.9±0.2	…	…
	14	…	…	…

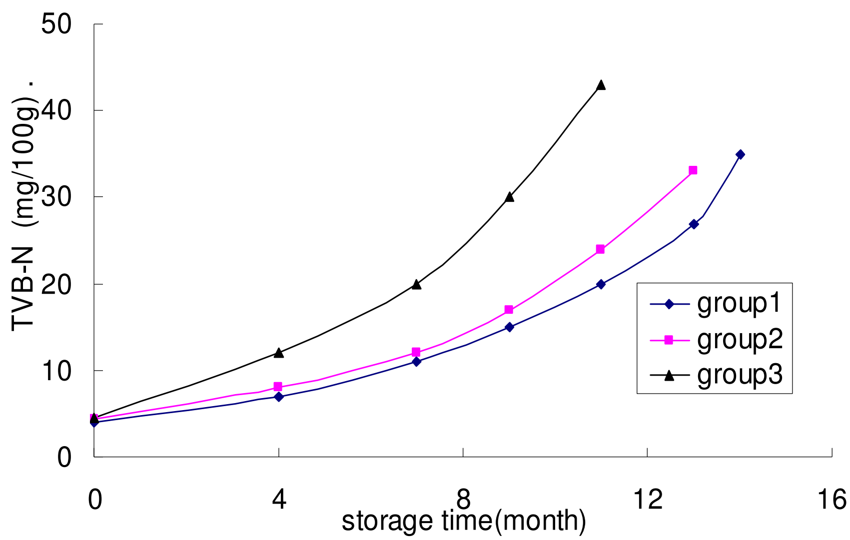

Figure 5. TVB-N value changed trend after cold transportation. Group 1 tilapia fillets were transported at -18°C stably; group 2 was transported in refrigerated vehicle; group 3 was transported by vehicle without refrigeration.

Shelf-life determination

Sensory evaluation and TVB-N value are the two important parameters to determine the shelf-life. Temperature is a critical parameter that affects sensory evaluation and TVB-N value during the cold chain (Abbas et al., 2008). Combining with sensory analysis and TVB-N value, smell score below 3 appeared at the 13th month, so 11 months was recommended as the shelf-life of group 1 tilapia fillet. Analogically, the group 2 can be stored for 9 months, the group 3 with 7 months. The most likely reason was that temperature fluctuation caused protein degradation and fat oxidation (Maria, 2009), furthermore, the reactions were accelerated to deteriorate tilapia fillet quality.

Conclusions

The paper described fish quality evaluation based on continuous temperature monitoring by RFID temperature recorder. There was no diversity on temperature of tilapia fillet samples in the refrigerated vehicle during 8 h transportation, based on SAS software ($P > 0.05$). The ambient temperature of cooling air exit point had the largest fluctuation range of 30℃, the other points fluctuated gently. Ambient temperature fluctuated more rapidly than frozen tilapia fillet inside the vehicle.

The rate of quality deterioration was an accelerated process with the passage of storage time by means of sensory evaluation score and TVB-N value. The cold chain had a positive effect on shelf-life. Moreover, shelf-life of tilapia fillet temperature fluctuating within 0.5℃ had two months more than 2℃. Comparing with tilapia fillet without refrigeration, shelf-life extended to four months.

Shelf-life had a little difference between the results calculated by the methods of sensory evaluation and TVB-N value. Shelf-life based on sensory analysis was longer than TVB-N value in frozen tilapia fillets which were transported in refrigerated condition, in contrast, based on sensory analysis; it was shorter than TVB-N value in tilapia fillets in non-refrigerated transportation.

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REFERENCES

Abbas KA, Mohamed A, Jamilah B, Ebrahimian M (2008). A review on correlations between Fish Freshness and pH during cold storage. Am. J. Biochem. Biotechnol. 4(4): 416-421.

Arannilewa ST, Salawu SO, Sorungbe AA, Ola-Salawu BB (2005). Effect of frozen period on the chemical, microbiological and sensory quality of frozen tilapia fish (Sarotherodun galiaenus). Afr. J. Biotechnol. 4(8): 852-855.

Barroso M, Careche M, Borderias AJ (1998). Quality control of frozen fish using rheological techniques. Trends Food Sci Technol. 9: 223-229.

Fagan JD, Gormley TR, Mhuircheartaigh MU (2003). Effect of freeze-chilling, in comparison with fresh, chilling and freezing, on some quality parameters of raw whiting, mackerel and salmon portions. Food Sci. Technol-LEB. 36(7): 647-655.

Giannini D, Parin MA, Gadaleta L, Carrizo G (2007). Influence of raw material quality on quality of iced and frozen white fish products. J. Food qual. 24(6): 527-538.

Gram L, Huss HH (1996). Microbiological spoilage of fish and fish products. Int. J. Food Microbiol. 33: 121-137.

http://www.farming4profit.co.uk/downloads/Buildings-Tilapia.pdf. Accessed on July 24, 2009.

Jedermann R, Ruiz-Garcia L, Lang W (2009). Spatial temperature profiling by semi-passive RFID loggers for perishable food transportation. Comput. Electron Agr. 65(2): 145-154.

Koutsoumanis K, Nychas GE (2000). Application of a systematic experimental procedure to develop a microbial model for rapid fish shelf-life predictions. Int. J. Food Microbiol. 60: 171-184.

Laguerre O, Flick D (2007). Frost formation on frozen products preserved in domestic freezers. J. Food Eng. 79: 124-136.

Makarios-Laham IK, Lee T (1993). Protein hydrolysis and quality deterioration of refrigerated and frozen seafood due to obligately psychrophilic bacteria. J. Food Sci. 58(2): 310-313.

Manju S, Leema J , Srinivasa Gopal TK, Ravishankar CN, Lalitha KV(2007). Effects of sodium acetate dip treatment and vacuum-packaging on chemical, microbiological, textural and sensory changes of Pearlspot (Etroplus suratensis) during chill storage. Food Chem. 102: 27-35.

Maria M (2009). Biochemical and textural properties of frozen stored (-22℃) gilthead seabream (Sparus aurata) fillets. Afr J. Biotechnol. 8(7): 1287-1299.

Mikko K (2003). Increasing efficiency in the supply chain for short shelf life goods using RFID tagging. Int. J. Reta Dist. Manage. 31(10): 529-536.

Nielsen MK, Jorqensen BM (2004). Quantitative relationship between trimethylamine oxide aldolase activity and formaldehyde accumulation in white muscle from gadiform fish during frozen storage. J. Agr. Food Chem. 52(12): 3814-3822.

Shimoni E, Anderson EM, Labuza TP (2001). Reliability of time temperature indicators under temperature abuse. J. Food Sci. 66(9): 1337-1340.

Sivertsvik M, Jeksrud WK, Rosnes JM (2002) .A review of modified atmosphere packaging of fish and fishery products – significance of microbial growth, activities and safety. Int. J. Food Sci. Technol. 37(2): 107-127.

SAS (2002) Statistical Analysis System Proprietary software. Release 8.3. SAS Institute Inc., Cary, NC USA.

Taoukis PS, Labuza TP (2003). Time-temperature indicators (TTIs). In: Ahvenainen R Editor, Novel Food Packaging Techniques, Woodhead Publishing Limited, UK, pp. 103-126.

Tejada M, Huidobro A, Mohamed GF (2006). Evaluation of two quality indices related to ice storage and sensory analysis in farmed gilthead seabream and seabass. Food Sci. Technol. Int. 12(3): 261-268.

Tijskens LMM, Polderdijk JJ (1996). A generic model for keeping quality of vegetable produce during storage and distribution. Agr. Syst. 51(4): 431-452.

Tsironi T, Dermesonlouoglou E, Giannakourou M, Taoukis P (2008). Shelf-life modelling of frozen shrimp at variable temperature conditions. LWT-Food Sci. Technol. 42(2): 664-671.

Tsironi T, Gogou E, Velliou E, Taoukis PS (2008). Application and validation of the TTI based chill chain management system SMAS (Safety Monitoring and Assurance System) on shelf-life optimization of vacuum packed chilled tuna. Int. J. Food Microbiol. 128: 108-115.