Development of functional canned and pouched tuna products added inulin for commercial production

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Abstract Four formulas of canned tuna in spring water and tuna in mayonnaise and pouched tuna in salad cream and tuna in thousand island cream with added inulin were developed for commercial production. The effects of the addition of a prebiotic (inulin, Orafit®-HP) on the color and sensory properties of these products were studied. For inulin concentrations studied (3, 5, 7 and 10 %, w/w) caused more intensified yellow and red colors. Hedonic sensory values of tuna packed in spring water and in mayonnaise showed no significant differences ($p>0.05$) among products with different inulin addition levels (3, 5, 7 and 10 %, w/w) in terms of color, flavor, sweetness and overall characteristics. However, when packed in thousand island cream, significant differences ($p<0.05$) in color and overall characteristics were found when inulin was added higher than 7 %. Tuna in salad cream showed significant differences ($p<0.05$) in color, flavor, sweetness and overall characteristics at higher than 7 % inulin. The panelists showed acceptable overall liking scores at upto 7 % inulin of all tuna products. The thermal sterilization process resulted in approximately 20 % decrease in final inulin content. The calculated residual fructans of finished products at shelf life of 3 years were 3.01, 2.78, 2.90 and 2.84 % for tuna in spring water, tuna in mayonnaise, tuna in thousand island and tuna in salad cream, respectively. Considering formula cost in a commercial production and the recommended daily intake (RDI) of inulin in the finished product at end of shelf life (≥ 3 g/d), an addition of 5 % inulin for tuna in spring water and 7 % inulin for tuna in mayonnaise, tuna in thousand island and tuna in salad cream are recommended.

Keyword Tuna product · Inulin · Product development · Sensory · Dietary fiber · Prebiotic

Introduction

Recent food consumer trends have changed in their food purchase intent towards food for health. The demand for functional foods is growing rapidly, that is for foods that provide not only basic nutrition but also other health benefits. These special qualities will help to reduce health risk such as the reduction of cholesterol levels in blood, prevention of cancer, obesity and diabetes. In this regard, functional foods play an outstanding role. The increasing demand for such foods can be explained by the increasing cost of healthcare and increase life expectancy (Siro et al. 2008). Consumers have become increasingly aware of the need to maintain their health through nutrition including the role of gut flora in health and disease.

A functional food ingredient has some health benefits i.e., ingredients containing a specific health benefit substance such as the addition of prebiotic. Prebiotic is non-metabolizable carbohydrates, which can promote the growth of beneficial gut microorganisms and probiotics. This results in healthy consumers, especially in terms of the gut, immunity and digestive system (Rastall 2000). Adding an indigestible carbohydrate and a prebiotic, which has been linked to improved colon health, and an increased absorption of calcium and minerals, increases the marketability of such products (Gonzalez et al. 2011). Prebiotics are non-digestible food components (primarily oligosaccharides) which escape digestion in the upper gut, and are fermented by probiotics or other beneficial bacteria. They are distinguished from other dietary fibers because it has a special property for selective fermentation by bifidobacteria/lactobacilli within the gut microflora

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producing useful intermediates such as short and medium chain fatty acids and vitamins B (Tuohy et al. 2005).

Prebiotics are a food ingredient which resists digestion in the upper gut and they reach the colon where they are utilized preferentially by selected groups of beneficial bacteria. Modulation of the human gut flora by prebiotic substances has a potential benefit to human health by enhancing the levels of 'beneficial' gut bacteria (Dandan et al. 2008). Non-digestible inulin-type fructans, such as FOS, inulin and oligofructose are known promote bifidobacteria (Buddington et al. 1996) and other good bacteria resulting in prebiotic effect in humans (Bouhnik et al. 1999; Harmsen et al. 2002). Fructan contains highly soluble inulin (HSI) and oligofructose (OF) with effects in fecal culture, leading to an increase in bifidobacteria and lactobacilli (Pompei et al. 2008). They are used as dietary fiber supplements or as food ingredients in several food products (Roberfroid 2007; Wichienhot and Chinachoti 2011). Inulin allows fat replacement in spreadable products, for instance table spreads, butter-like products, cream cheese and processed cheese (Hennelly et al. 2006).

Meat and meat products are valuable in the world economy but meats are enriched with high protein and lipids. Meat-based functional foods have the opportunity to improve their image regarding the needs of consumers. These changes affect several functional components to replace macronutrient and to modify of the culture population in ways that would increase the bioactives (Jimenez-Comenero 2007).

Canned tuna mainly provides a good source of protein and, with dietary fiber addition in the form of a prebiotic can be an option to balance gut microflora (Swanson and Fahey 2006). The results hopefully would be to offer additional nutritional advantages for canned tuna products. The objectives of this research were to develop canned and pouched tuna products with added inulin, and acceptable and aesthetic qualities. In this research the effects of thermal process and storage on inulin loss were investigated.

Materials and methods

Materials

Tuna (*Thunnus tonggol*) meat was kindly supplied by Tropical Canning Public Company Limited, Songkhla, Thailand. Tuna meat was prepared in the form of tuna chunks in spring water and of tuna flakes in mayonnaise, tuna flakes in salad cream and tuna flakes in thousand island cream. Inulin (Orafti®-HP, BENEIO-Orafti, Thienen, Belgium) was added to each product at concentrations of 0 % (control), 3 %, 5 %, 7 % and 10 % (w/w).

Development of formula

The study used 4 standard formulas of tuna products (canned tuna in spring water and tuna in mayonnaise and pouched tuna in salad cream and tuna in thousand island cream) with addition of various concentrations of inulin. Formulation of tuna in spring water was done by dissolving of inulin powder in spring water pre-heated at ≤ 65 °C before filling with tuna meat in can. Preparation of the emulsion products, canned tuna in mayonnaise, pouched tuna in salad cream and pouched tuna in thousand island cream, were carried out by addition of inulin powder with other dried ingredients.

Color measurement

The colors of the finished products (4 formulas) were measured with a Chroma Meter colorimetric Hunter Lab model Color Flex, using the CIE-Lab system for the illuminant D65 and 10° angle of vision. The parameters registered were: L^* = lightness (where 0=black and 100=white), ($+a^*$ =redness and $-a^*$ =greenness), ($+b^*$ =yellowness and $-b^*$ =blueness) and compared to a standard white calibration plate. The color measurement was done in triplicate.

Viscosity measurement

The rheological behavior of the tuna products was determined for viscosity using a Brookfield viscometer DV II+Pro. The measurement was carried out at 25 °C with spindle no. 3 at 50 rpm. The finished products after passed through commercial sterilization, 300 ml of the mayonnaise, salad cream and thousand island cream samples were measured of viscosity in triplicate. Viscosity of spring water added inulin could not be measured due to its too low similar to water moreover it had less volume in the formula for measurement in this condition. The viscosity was reported in centipoise (cP) unit.

Sensory evaluation

Seven trained and experienced panelists in tuna products were selected from Tropical Canning Company's staff. Sensory evaluation was evaluated using a questionnaire and testing exercises. Two forms of sensory analysis were considered: discrimination analysis asking to differentiate products, using difference from control test for color, flavor, sweetness and overall acceptability. The 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely) was used to rank among formula with varying added inulin. Comparisons between samples and the control for color, sweetness and overall acceptability, using R-Index were performed. R-Index was the degree of difference between control and samples whereas control was respective formula without addition of inulin. The different levels of attributes were from 1 (no different) to 7

(extremely different). The samples were served to the panelists in 20-mL plastic cups covered with lids. The panelists were provided with water and bread for tuna in mayonnaise, tuna in salad cream and tuna in thousand island cream. Each sample was labeled with a random 3-digit code, and served in a random order to each panelist.

Determination of inulin (fructan) content

Fructan analysis was done by using a commercial test kit, a modification of the AOAC Method 999.03 and AACC Method 32.32, from Megazyme Company, Ireland (USA). Sucrose, starch and maltooligosaccharide were hydrolyzed using the combined action of an enzyme mix (sucrase, β -amylase, pullulanase and maltase). Reducing sugars were reduced to sugar alcohols by treatment with alkaline borohydride. Fructan and inulin were then hydrolyzed to fructose and glucose with fructanase and the released sugars were measured photometrically after derivatization with *p*-hydroxybenzoic acid hydrazide (PAHBAH) (Bohm et al. 2006).

Stability of inulin exposed to thermal processing during commercial sterilization

The thermal stability of the products was investigated. The addition of premixed and inulin in tuna product samples was followed by sterilization at a temperature of 116 °C for 70 min. After being sterilized, all samples were cooled to an ambient temperature (28 ± 2 °C) and the qualitative determination of inulin content was made before and after sterilization. A heating stability measurement was carried out for the fructan content.

Shelf-life study on the inulin content and sterility of the finished products

During the shelf-life study, all the finished products, with an addition of 5 % inulin, were stored at ambient temperature and accelerated condition at 37 °C and 55 °C. Samples were taken at 1, 2, 3, 4, 5 and 6 months. The determination of the inulin was assessed using a fructan test kit. Sterility test of all products were performed according to BAM method (2001). Four cans or pouches of each finished product after storage at ambient temperature for 2 years was taken for microbiological examination (mesophiles aerobe, mesophiles anaerobe, thermophiles aerobe and thermophiles anaerobe). For tuna in salad cream and tuna in thousand island cream (acid food with pH 4.6 and below), yeast & mold count was additionally enumerated.

Microbial examination for sterility test of the finished products

A brief description of sterility test for tuna in spring water and tuna in mayonnaise (low-acid food with $\text{pH} \geq 4.6$), sample was blended and weighted 1 g sample before inoculated in test tubes containing 10 ml cooked meat medium (CMM). Sample was incubated at 35 °C for 96 h and 55 °C for 72 h. Turbidity of broth was observed for microbial growth. In case of no turbidity was found, its mean sample was completely sterile and no *Clostridium* sp. contamination. For determination of flat sour bacteria, similar method was performed using bromocresol purple broth. Sterility test for tuna in salad cream and tuna in thousand island cream (acid food with $\text{pH} < 4.6$), 1 g sample inoculated in 10 ml orange serum broth. Sample was incubated at 30 °C for 96 h and 55 °C for 72 h. Turbidity of broth was observed for microbial growth. In case of no turbidity was found, its mean sample was completely sterile and no butyric anaerobe and thermophilic bacteria contamination. For determination of mesophile acid tolerant bacteria, similar method was performed using malt extract broth and incubated at 30 °C. In case of turbidity was observed, that mean sample was not sterile then types and amount of microbial contamination must be further fully characterized according to BAM method (2001).

Statistical analysis

The statistical analysis was performed using SPSS software with version 16.0 for Windows to calculate mean $\pm$ SD of values measured for each sample. Analysis of variance (ANOVA) was applied with the least significant difference test (Duncan). The level of significance used was 95 % ($p < 0.05$).

Results and discussion

Color measurement

Color measurement in tuna in spring water products was observed. Color, represented by L^* (lightness), a^* (redness), b^* (yellowness) parameters, showed that tuna in spring water with inulin added was significantly slightly higher values for yellowness compared with the control ($p < 0.05$). The highest b^* value (37.70) was found in 10 % inulin, a significant increase compared with the control sample. Addition of inulin also affected redness and lightness. In this experiment, addition of inulin to three emulsion products (tuna in mayonnaise, in thousand island cream and in salad cream) showed that both the redness and yellowness gradually increased (Table 1). Brown color presumably from Maillard reaction between

Table 1 Average color values for tuna products added with different inulin concentration

Treatment	Color		
	L*	a*	b*
Tuna in spring water			
Control	91.04±0.25 ^{ab}	−0.26±0.03 ^c	20.66±0.08 ^d
Inulin 3 %	76.85±0.16 ^c	0.95±0.01 ^a	24.62±0.33 ^c
Inulin 5 %	89.13±0.68 ^b	−0.49±0.06 ^d	25.45±0.25 ^c
Inulin 7 %	91.76±0.10 ^a	−0.61±0.01 ^e	29.58±0.02 ^b
Inulin 10 %	89.88±0.04 ^{bc}	0.20±0.00 ^b	37.70±0.21 ^a
Tuna in mayonnaise			
Control	87.99±0.77 ^b	−0.29±0.28 ^b	13.16±0.43 ^d
Inulin 3 %	87.85±0.28 ^b	0.27±0.05 ^b	14.02±0.27 ^c
Inulin 5 %	88.92±0.12 ^a	0.36±0.05 ^b	13.58±0.08 ^{cd}
Inulin 7 %	88.29±0.61 ^b	1.13±0.42 ^a	14.87±0.08 ^b
Inulin 10 %	88.93±0.31 ^a	1.59±0.27 ^a	15.69±0.26 ^a
Tuna in thousand island cream			
Control	73.88±0.24 ^a	14.79±0.46 ^a	30.77±0.11 ^b
Inulin 3 %	73.86±0.53 ^a	14.61±0.20 ^b	30.93±0.39 ^b
Inulin 5 %	71.90±0.19 ^b	15.61±0.38 ^a	32.86±0.44 ^a
Inulin 7 %	71.49±0.27 ^b	14.73±0.92 ^b	32.68±0.86 ^a
Inulin 10 %	71.16±0.44 ^b	14.92±0.31 ^a	32.57±0.27 ^a
Tuna in salad cream			
Control	82.35±0.35 ^a	1.44±0.83 ^d	12.34±0.21 ^c
Inulin 3 %	80.22±0.68 ^b	1.80±0.46 ^c	13.90±0.16 ^d
Inulin 5 %	78.90±0.29 ^c	2.17±0.38 ^b	16.35±0.74 ^c
Inulin 7 %	78.22±0.14 ^c	2.24±0.29 ^b	17.48±0.28 ^b
Inulin 10 %	76.56±0.42 ^d	2.63±0.53 ^c	18.44±0.51 ^a

Values with different superscripts within the same column in the same product, mean it has significantly difference ($p < 0.05$)

Control means a typical formula without addition of inulin

reducing sugars and amino acids was observed. This is a common reaction in foods which undergo thermal processing (Jaeger et al. 2010). The color values showed similar profiles in all the tuna products. The “L*, a*, and b*” values were slightly decreased compared to the control. It could be concluded that a higher inulin concentration has an effect on the color of products.

It has been reported that inulin enriches products in terms of lightness (L*), redness (a*) and yellowness values which increased in direct proportion to the concentration of inulin (Berian et al. 2011). A similar trend in the higher concentration of fructooligosaccharide seems to produce a slight increase in the redness and yellowness of cooked sausages (Caceres et al. 2004). The color of the inulin/FOS enriched products was found to be darker. This is explained by the greater number of reducing ends involved in a Maillard reaction. Thus shorter chain inulins result in even darker colors as

they possess lower molecular weight fructans (Peressini and Sensidoni 2009).

Sensory evaluation

The effects of inulin on the sensory characteristics of tuna products were investigated. The hedonic scores showed the effects of adding different inulin concentrations on the sensory properties of tuna products studied. As shown in Table 2, the addition of 3–7 % of inulin in spring water tuna products and tuna in mayonnaise made no significant differences ($p > 0.05$) for color, flavor, sweetness and overall acceptability. The sensory properties of tuna in thousand island showed significant differences ($p < 0.05$) for color and overall liking. The addition of 10 % of inulin had an effect on color. Tuna in salad cream showed significant differences ($p < 0.05$) for color, flavour, sweetness and overall. Two types of inulin showed no significant difference in odour; however, they were significant different in the flavor of kefir (Glibowski and Kowalska 2012). There was no significant difference ($p > 0.05$) between the scores for the odor and color of dry fermented sausages with added inulin (Mendoza et al. 2001). All the products were considered and the acceptable mean overall scores were above 5 (neither like nor dislike). Nevertheless, tuna in thousand island cream with an added 7 % of inulin was given the lowest score at 4.71 (dislike). The acceptance of consumer from hedonic score seems to be varying depends on food complex in physical property particular viscosity in emulsion system (Witczak et al. 2014). Inulin in food matrix has been reported that they had interaction to other food components which affected to rheological, microstructural and sensory property of reduced-fat stirred yoghurt (Crispín-Isidro et al. 2014), orange-juice (Saavedra-Leos et al. 2014), sugar-free chocolate (Aidoo et al. 2014), cooked meat batters (Álvarez and Barbut 2013). Furlan and co-worker (2014) reported that optimal combination of plasma protein (2.5 % w/w) and inulin (2 % w/w) had the best acceptability by consumer for reduced-fat minced meats. In this study showed that trend of acceptability of thousand island cream and salad cream at 7 % inulin were different. It might due to the food compositions in thousand island cream and salad cream were different thus different in food matrix with inulin.

The R-Index was the degree of difference between control and samples and it was used to compare the sensory characteristics. The different levels of attributes were from 1 (no different) to 7 (extremely different). This showed that the sensory properties had no significant differences ($p > 0.05$) for color, except for Tuna in mayonnaise which had a significant difference ($p < 0.05$). The scores showed that it had significant differences ($p < 0.05$) for sweetness and overall as shown in Table 3. The addition of carageenan and inulin increased the sweetness of low fat custard (Tarrega et al. 2010). The addition of inulin leads to a higher level of

Table 2 Average values for sensory attributes of tuna products added with different inulin concentration by Hedonic-9 point

Treatment	Color	Flavor	Sweetness	Overall
Tuna in spring water				
Control	7.00±0.22 ^a	6.86±0.63 ^a	6.14±0.31 ^a	6.86±0.53 ^a
Inulin 3 %	6.00±0.22 ^a	6.14±0.63 ^a	5.00±0.31 ^a	6.43±0.53 ^a
Inulin 5 %	7.14±0.57 ^a	7.00±0.46 ^a	6.43±0.34 ^a	6.43±0.68 ^a
Inulin 7 %	6.29±0.39 ^a	6.71±0.87 ^a	6.43±0.29 ^a	6.57±0.43 ^a
Inulin 10 %	6.29±0.18 ^a	6.43±0.26 ^a	5.00±0.58 ^a	5.86±0.32 ^a
Tuna in mayonnaise				
Control	6.57±0.61 ^a	6.29±0.57 ^a	6.43±0.43 ^a	6.57±0.72 ^a
Inulin 3 %	6.43±0.32 ^a	6.57±1.03 ^a	6.57±0.24 ^a	6.43±0.58 ^a
Inulin 5 %	6.57±0.79 ^a	6.71±0.42 ^a	6.71±0.86 ^a	6.71±0.34 ^a
Inulin 7 %	6.43±0.38 ^a	5.86±0.28 ^a	5.71±0.45 ^a	5.43±0.19 ^a
Inulin 10 %	6.43±0.44 ^a	6.14±0.50 ^a	6.14±0.64 ^a	6.14±0.63 ^a
Tuna in thousand island cream				
Control	7.57±0.88 ^a	7.00±0.34 ^a	5.57±0.32 ^a	6.57±0.17 ^a
Inulin 3 %	7.43±0.42 ^{ab}	6.57±0.25 ^a	6.14±0.28 ^{b a}	6.43±0.36 ^a
Inulin 5 %	6.57±0.62 ^{ab}	6.86±0.57 ^a	5.86±0.49 ^a	6.29±0.72 ^a
Inulin 7 %	6.57±0.31 ^{ab}	5.57±0.20 ^a	5.14±0.42 ^a	4.71±0.56 ^b
Inulin 10 %	6.14±0.47 ^b	6.29±0.68 ^a	5.71±0.51 ^a	5.71±0.43 ^{ab}
Tuna in salad cream				
Control	7.00±0.24 ^a	5.57±0.46 ^b	5.86±0.18 ^a	5.71±0.30 ^b
Inulin 3 %	6.29±0.56 ^{ab}	6.29±0.28 ^{ab}	5.57±0.42 ^a	5.86±0.54 ^b
Inulin 5 %	5.71±0.49 ^b	5.86±0.23 ^b	5.29±0.25 ^a	5.71±0.4 ^b
Inulin 7 %	6.43±0.81 ^{ab}	7.00±0.32 ^a	6.86±0.64 ^b	7.00±0.63 ^a
Inulin 10 %	6.00±0.62 ^{ab}	6.43±0.47 ^{ab}	5.86±0.58 ^a	5.71±0.39 ^b

Values with different superscripts within the same column in the same product, mean it has significantly difference ($p < 0.05$)

Control means a typical formula without addition of inulin

sweetness due to the degradation of the long fructose chain generating di-D-fructose dianhydrides in the product (Bohm et al. 2005).

Effects of thermal processing on inulin content

The inulin content before and after commercial sterilization was compared (Fig. 1). The commercial sterilization process was performed at 116 °C for 70 min for the canned tuna products; tuna in spring water and tuna in mayonnaise. They were processed at 114 °C for 60 min for the pouched tuna products, tuna in thousand island and tuna in salad cream. The percentage of fructan after the thermal treatment of the products added 3, 5, 7 % and it was found that the inulin content decreased up to 20 %. The inulin content decreased with the increasing temperature. This result agreed with previous reports that processing temperature leads to a degradation of the long fructose chains (fructan) to fructose monomers (Bohm et al. 2005; Wang et al. 2009). Moreover, high temperature and low pH may cause partial hydrolysis of these carbohydrates (Huebner et al. 2008). The dry heating of inulin from chicory at temperatures between 135 and 195 °C for 60 min

resulted in the significant degradation of the fructan ranging from 20 to 100 %. In general only high temperatures at low pH caused a significant reduction in prebiotic activity (Bohm et al. 2005).

Furthermore, inulin contained in rye bread baked for 60 min at 210 °C showed a loss of inulin ranging between 10 and 20 % (Fretzdorff and Welge 2003). Fructooligosaccharide degradation had occurred in the processing temperature range of 60–100 °C. The rate of degradation depends on the processing time and the proton concentration of the solution notably in the range of pH at 2.7 to 3.3 (Matusek et al. 2009). The processing had a significant influence ($p < 0.05$) on the fructan content for puree with added inulin. High hydrostatic pressure (500 mPa/1.5 min/20 °C) gave higher fructan content than the thermal process by pasteurization at 90 °C for 10 min (Keenan et al. 2011). Fructooligosaccharide are liable to hydrolysis in the conditions occurring during the pasteurization of fruit juices and drinks. The amount of hydrolysed saccharides is greater at a lower pH range from 2.7 to 4.2, longer heating time and higher temperature. The degree of hydrolysis of FOS with high heating effects can even reach values of over 80 % (Klewicki 2007).

Table 3 Average values for sensory attributes of tuna products added with different inulin concentration by R- Index

Treatment	Color	Sweetness	Overall
Tuna in spring water			
Inulin 3 %	2.43±0.27 ^a	1.71±0.18 ^b	2.00±0.34 ^b
Inulin 5 %	3.00±0.14 ^a	2.29±0.09 ^{ab}	2.57±0.32 ^{ab}
Inulin 7 %	2.86±0.62 ^a	2.00±0.35 ^b	2.57±0.21 ^{ab}
Inulin 10 %	2.71±0.33 ^a	3.43±0.24 ^a	3.51±0.48 ^a
Tuna in mayonnaise			
Inulin 3 %	1.29±0.68 ^b	3.43±0.24 ^a	3.43±0.52 ^a
Inulin 5 %	2.43±1.06 ^a	2.86±0.31 ^{ab}	3.57±1.26 ^a
Inulin 7 %	2.00±0.57 ^{ab}	2.29±0.52 ^b	3.00±0.76 ^a
Inulin 10 %	3.00±0.79 ^a	3.00±0.41 ^{ab}	3.57±0.65 ^a
Tuna in thousand island cream			
Inulin 3 %	2.00±0.23 ^a	2.71±0.16 ^a	2.71±0.22 ^b
Inulin 5 %	2.14±0.11 ^a	2.43±0.38 ^a	3.00±0.19 ^{ab}
Inulin 7 %	2.71±0.38 ^a	3.14±0.26 ^a	4.00±0.24 ^a
Inulin 10 %	2.86±0.34 ^a	2.86±0.44 ^a	3.57±0.30 ^{ab}
Tuna in salad cream			
Inulin 3 %	1.86±0.09 ^a	2.71±0.31 ^a	2.86±0.18 ^a
Inulin 5 %	2.00±0.16 ^a	2.71±0.26 ^a	2.71±0.28 ^a
Inulin 7 %	2.43±0.32 ^a	2.57±0.11 ^a	2.86±0.31 ^a
Inulin 10 %	2.43±0.28 ^a	2.71±0.15 ^a	3.14±0.39 ^a

Values with different superscripts within the same column in the same product, mean it has significantly difference ($p < 0.05$)

Viscosity measurement

The tuna products (mayonnaise, salad cream and thousand island cream) after commercial sterilization were further determined on their viscosity. The rheological behavior shows similar profiles in all samples as shown in Table 4. The addition of inulin resulted in significantly ($p < 0.05$) increased of viscosity. Tuna in mayonnaise increased viscosity about 6 fold, but about 2 fold in tuna in thousand island cream and tuna in salad cream. This might be due to food matrix interaction between inulin and other food components were different. In addition, compositions of cream in thousand island cream and salad cream were the same but different from mayonnaise cream. It has been reported that inulin could increase viscosity and it could be used as fat-replacer in emulsion foods. Inulin had interaction with other food components which affected to rheological, microstructural and sensory property (Witczak et al. 2014). This phenomenon due to the fact that after inulin particles is suspended or dissolved in water or other aqueous liquids at high concentration causes submicron crystalline inulin particle form a tridimensional gel network. This resulted in an increase in viscosity (Glibowski 2010; Roberfroid 2005). Addition of three types of inulin in dairy products can significantly change

their rheological behavior by increasing their viscosity (González et al. 2009; Tarrega and Costell 2006).

Effect of storage on inulin content in finished products

The changes in the inulin (fructan) content during storage were studied. The addition of 5 % inulin was chosen for reason of economic for commercial production and the acceptability of the residual inulin content more than 3 % in finished product. Recommended daily intake (RDI) of inulin is at least 3 g per day for bifidogenic effect (Coussement 1999; Meyer and Stasse-Wolthuis 2009). Experiments were designed to store the products in ambient conditions and in accelerated temperatures at 37 °C and 55 °C for 6 months with equivalent to 1 year and 3 years of shelf life, respectively. The results of the shelf-life are shown in Fig. 2. These results show that the inulin (fructan) content gradually declined in the ambient conditions and the accelerated temperature conditions at 37 °C, but rapidly declined with the temperature at 55 °C after storage for 6 months (equivalent to 3 years of shelf life). This study showed similar results to Bohm and co-worker (2005) who showed that inulin content decreased with temperature and storage time. The dry heating of inulin for up to 60 min at temperatures between 135 and 195 °C found a significant degradation of the fructan ranging from 20 to 100 %, depending on how the inulin was measured. The dry heating of inulin from Jerusalem artichoke at 195 °C for 30 min induced complete degradation of the fructan chains and a concomitant formation of low molecular degradation products, most likely di-D-fructose dianhydrides (Bohm et al. 2006). Higher degree of polymerization (DP) FOS (fructooligosaccharide) from onion bulb tissue was hydrolysed better than lower ones at storage and room temperatures (15–20 °C). The hydrolysis of the different high DP FOS occurred mainly during the first 2 months of storage. An increase during the same period is due to the production of new DP6 FOS arising from the hydrolysis of higher DP FOS at higher temperatures (Benkeblia and Shiomi 2006). All products in this study were passed through commercial sterilization process followed a factory's standard procedure for production of tuna in can and pouch. The thermal process was validated with F_0 of 6.0 min (actual thermal process of 116 °C, 70 min). All finished products after storage for 2 years at ambient temperature were examined by sterility test. It was found that negative on mesophiles and thermophiles aerobe and anaerobe of all finished products. Total coliform and yeast & mold counts were < 3 MPN/g and < 10 CFU/g of tuna in salad cream and tuna in thousand island cream, respectively. It consider that products were completely sterilized and no microbial contamination. So that all finished products were safe for consumption with shelf-life of 2 years.

Fig. 1 Effect of thermal process on inulin contents of tuna in spring water (a), tuna in mayonnaise (b), tuna in thousand island cream (c) and tuna in salad cream (d)

Table 4 Average rheology values of tuna products added with different inulin concentration

Treatment	Viscosity (cP)		
	Tuna in mayonnaise	Tuna in thousand island cream	Tuna in salad cream
Control	156.00±1.21 ^c	555.67±2.09 ^c	543.67±2.23 ^c
Inulin 3 %	299.33±2.32 ^d	629.33±1.35 ^d	601.67±3.21 ^d
Inulin 5 %	470.00±1.09 ^c	710.67±1.24 ^c	658.67±3.48 ^c
Inulin 7 %	575.33±1.88 ^b	904.67±3.15 ^b	872.67±2.34 ^b
Inulin 10 %	906.00±3.61 ^a	1284.33±2.74 ^a	1215.00±4.08 ^a

Values with different superscripts within the same row in the same product, mean it has significantly difference ($p < 0.05$)

Control means a typical formula without addition of inulin

Conclusion

This study showed that the addition of inulin affected the physical properties, sensory properties and caloric values in finished product. The results showed that sensory attributes were not significant different ($p > 0.05$) for color, flavour, sweetness and overall in tuna in spring water and tuna in mayonnaise. The sensory evaluation results showed that all experienced panelists accepted products. It is possible to add up to 7 % inulin. It was concluded that the addition of 5 % inulin in aseptically processed tuna products were suitable for reasons of economy for commercial production and the acceptability of the residual inulin content in the finished products. During the storage time of the finished products, the inulin (fructan) content decreased with increasing temperature and time. The residual fructans of tuna in spring water, tuna in mayonnaise, tuna in thousand island and tuna in salad cream

Fig. 2 Effect of storage conditions on inulin contents of tuna in spring water (a), tuna in mayonnaise (b), tuna in thousand island cream (c) and tuna in salad cream (d)

at calculated shelf life of 3 years were 3.01, 2.78, 2.90 and 2.84 %, respectively. According to the recommended daily intake (RDI) of inulin at least 3 g/d, 5 % inulin addition in tuna in spring water and 7 % inulin addition for tuna in mayonnaise, tuna in thousand island and tuna in salad cream are recommended. Many evidences have shown that inulin has prebiotic property influencing on gut microbial by promoting beneficial bacteria (probiotic) (Komatsu et al. 2013; Adebola et al. 2013) and it is a good source of low calorie dietary fiber. The addition of inulin could be an alternative way to apply in healthy tuna products. Therefore, 5 % inulin (Orafti® HP) was recommended to add in canned tuna in spring water and 7 % addition for canned tuna in mayonnaise and pouched in salad cream and tuna in thousand island. These tuna formulations were succeeded in sensory acceptance and acceptable in inulin (fructan) content at higher than 3 % in finished products after commercial sterilization process and during storage for calculated shelf life of 3 years. After storage for 2 years at ambient temperature ($28 \pm 2^\circ\text{C}$), all finished products were sterile and safe for consumption. In addition, the formulations and

process of making these products added inulin were patented, being registered and preparing for commercial production.

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Conflicts of interest statement The authors declare they have no conflicts of interest.

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