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Evaluation of the Quality of Canned Seafood with Added Spice-oil Extract

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Abstract

The influence of spice (cinnamon, allspice, black pepper)-oil extract on canned seafood quality was studied. During the processing of canned seafood, the substitution of spice-oil extract for vegetable oil (refined sunflower, corn, soybean and olive oil) resulted in a decrease in the heat resistance of spore microorganisms, making it possible to reduce the duration of sterilization for canned food to 5-10 min at 115°C. This reduction in the sterilization duration of canned seafood with spice-oil extract inhibited residual microflora in the product, thus reducing the deleterious effect of heating on the main food compounds while preserving protein digestibility.

Key words: Spice-oil extract, Canned foods, Heat resistance, Sterilization, Digestibility, Fatty acids

Introduction

Microbiological safety is a fundamental property to be considered in the creation and development of technology for food processing and preservation. Some techniques used to ensure microbiological safety, including the addition of preservatives, increases in acidity, and high-temperature processing, result in the destruction, inactivation or growth stabilization of microorganisms. However, such measures often lead to reductions in food quality.

For food preservation, canning, a technology that relies on high-temperature processing or sterilization, provides a reliable means of securing microbiological safety. In most countries, including Russia, the sterilization of fish and non-fish food products is conducted to kill spoiling and pathogenic organisms (Giprorybflot, 1996; Shul'gina, 1995). As a quality test organism, highly heat-resistant spores of *Clostridium sporogenes-25* (*C. sporogenes-25*) are targeted.

Although the sterilization process secures microbiological safety, it results in the loss of native properties of products and has some undesirable effects, including the accumulation of products of nutrient destruction, the formation of high-molecular-weight nitrogen compounds, and reductions in food digestibility and assimilation (Shvydkaya and Blinov, 2008; Shulgin, 2006; Shulgin et al., 2006). A well-known method of reducing the heat resistance of spore microorganisms in canned seafood and decreasing the requisite rigidity of sterilization modes is through the creation of an acidic environment in the canned product (Mazokhina-Porshnyakova et al., 1977), which is barely acceptable for fish and non-fish goods canned

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in oil. This method allows for effective sterilization without an excessive thermal load on canned food, thus guaranteeing the commercial sterility of food products. The aim of this work was to investigate the influence of spice-oil extract on the heat resistance of microorganisms in canned seafood, the modes of product sterilization, and the quality of the product.

Materials and Methods

Preparation of canned food

The preparation of semi-finished canned seafood products was carried out in accordance with "The technological instructions for preparing canned seafood from non-fish objects" (Giprorybflot, 1989). The following ingredients were used in canning: frozen sea cucumber, frozen octopus, frozen surf clam, frozen squid, frozen whelk, frozen sea scallop, frozen mussels, refined sunflower, corn, soybean and olive oils, edible salt, powdered black pepper, powdered allspice and milled cinnamon. Spice-oil extract was prepared as follows; milled spices (cinnamon, allspice, black pepper) and vegetable oils were mixed, heated and incubated at 80°C for 24-36 h. The mixture was cooled and the sediment and spice-oil were separated (Lazhentseva et al., 2011). The cut and washed seafood meat was placed on grids in a smoking room. The flue-curing mode was employed for 20 min at 23-25°C, until the seafood attained the mellow flavor and light aroma of smoked seafood meat. The prepared seafood was batched by size and packed in 90-g glass jars. Twenty cubic centimeters of spice-oil extract or vegetable oil were poured into the experimental and control jars of canned seafood, respectively. The spice-oil extract was a clear flavored oil with a brownish tinge and pleasant cinnamon smell, from which microorganisms were absent (Lazhentseva, 2011). After filling, the jars were rolled using a vacuum, and the patterns of their heating during the sterilization process in water at a counter pressure of 0.18MPa at 115°C in an AV-2 autoclave were investigated. To compare canned food quality, five experimental cans of each product and five control cans of seafood with added vegetable oil were sterilized.

Sterilization mode

The canned seafoods, namely, smoked mixed seafood in oil, smoked sea cucumber in oil and smoked surf clams in oil, were produced according to recommendations for developing the sterilization modes of canned fish and fish products (Giprorybflot, 1996; Agribusiness, 2004; Flaumenbaum, 1986).

A suspension of spores of *C. sporogenes*-25, a known specific spoiling pathogen of canned seafood, was obtained from the Laboratory of Microbiology, Giprorybflot Institute, Russia, and was used to determine the heat resistance of spore-forming bacteria. The heat resistance of spore microorganisms in the product was determined by the capillary method (Flaumenbaum, 1986). *C. sporogenes*-25 spores were characterized by their heat resistance in a phosphate-buffered solution $D_{121°C} = 0.58$ min. The reliability of pre-developed sterilization modes was assessed under laboratory conditions by artificially infecting canned seafood in which the vegetable oil was completely replaced by spice-oil extract. *C. sporogenes*-25 spores (n=38,000) were introduced into the center of the contents of 30 110-g-net-weight glass jars of canned seafood. The infected canned goods in glass jars were sterilized in water at counter pressure (0.18 MPa) and then cooled by water at counter pressure.

The constant of the spore heat resistance Dt, where t is a constant temperature, at which 90% of cells die during time interval D, was calculated graphically. The experiment was repeated three times for each extract. The arithmetic mean of the results from three experiments was used. The value of the normative sterilizing effect (Fn in conditional min) was calculated using formula (1):

$$F_n = D_{121°C} * (lg B/b + x) \quad (1)$$

where $D_{121°C}$ is the heating time in min required to reduce the amount of *Cl. sporogenes*-25 spores by a factor of 10; B is the initial number of microbial spores in one gram of product before heating at 121.1°C; b is the finite amount number of microbial spores surviving after heating; *lg* B/b is the logarithm of the surviving spores, taken with the opposite sign; and x is a correction to take into account deviation in the number of surviving cells after the heating of spores from the log scale of death. The thermo-physical characteristics of the canned food content and the factual sterilizing effect (F_f) were assessed using STF-9004 (manufactured by ELLAB, Denmark). The calculation of de facto lethality in sterilization modes was performed according to the manual of Flaumenbaum (1986). The factual lethality (F_f) of the sterilization mode is the stationary equivalent of the concrete non-stationary mode, expressed in conventional 121.1-degree min, which allows for the quantification of the microbiological efficiency of any sterilization mode. The value of F_f was calculated using formula (2):

$$F_f = I_p * [K_{f1} + K_{f2} + ... + K_{fn}] \quad (2)$$

where F_f is the time interval between temperature measurements in the can center and K_f is the value of the conversion coefficient at the moment of measurement.

Digestibility

The factual digestibility of canned seafood was determined using the biotesting method recommended by Shulgin et al. (2006).

Fatty acid analysis

The total lipids in a sample were extracted with chloroform/methanol according to the method of Bligh and Dyer (1959). Total lipids were separated into phospholipids and non-phospholipids using silica cartridges (Alltech, silica, 1.5 mL, 100 mg) according to the method of Juaneda and Rocouelin (1985). The fatty acid content was expressed as a percentage of individual FAME in relation to the total area of the chromatogram (AOAC, 1995).

Results and Discussion

First, the constant of heat resistance, $D_{121.1°C}$, was determined. This value was then used to calculate the normative sterilizing effects for canned seafood. Indicators of heat resistance and the calculated values of the normative sterilizing effects for canned seafood with the addition of vegetable oil and spice-oil extract are presented in Table 1. The lethal time for spores of the test strain, *C. sporogenes*-25 in all types of canned seafood with added spice-oil extract was lower than that of those canned with vegetable oil, which parallels previous findings on the effects of spice extract on spores (Lazhentseva, 2011).

Similarly, the calculated values of normative F_n for the experimental canned seafood were lower than those of the control product. The obtained data were used to determine the duration of sterilization of canned food, which provides the required values of the factual sterilizing effect (F_f).

Efficient heating time was determined by taking into account the heating of control and experimental canned seafood during sterilization at 115°C. The durations necessary for the effective sterilization of experimental samples were 5 min (smoked surf clam and smoked mixed seafood in oil) to 10 min (e.g. smoked sea cucumber in oil) shorter than those of the control samples (Table 2).

All canned goods were industrially sterile after sterilization. The addition of spice-oil extract to canned goods resulted in an attractive appearance and a weak aroma of spices.

The replacement of vegetable oil with spice-oil extract can be assessed as effective for its observed ability to decrease the necessary sterilization duration by 5 to 10 min, inflicting thermal damage on microbial contaminants while preserving proteins and biologically valuable nutrients (Brazhnikov, 1987; Gelfand, 1994; Mazokhina-Porshnyakova et al., 1977).

Table 1. Comparative values of the indicators $D_{121.1°C}$, F_n for canned seafood.

Title of canned seafood	$D_{121.1°C}$, min		F_n, continued min	
	Control	Experimental	Control	Experimental
Smoked surf clam in oil	0.75	0.66	5.28	4.64
Smoked mixed seafood in oil	0.75	0.67	5.28	4.72
Smoked sea cucumber in oil	0.89	0.70	6.27	4.93

Table 2. Duration of sterilization and factual sterilizing effect for the control and experimental canned seafood

Type of canned seafood	Canned seafood with addition					
	Vegetable oil			Spice-oil extracts		
	F_n, cond. min	Sterilization time	F_f, cond. min	F_n, cond. min	Sterilization time	F_f, cond. min
Smoked surf clam in oil	5.28	20-50-20[1]	6.90	4.64	20-50-20	5.80
Smoked mixed seafood in oil	5.28	20-50-20	6.90	4.72	20-50-20	5.87
Smoked sea cucumber in oil	6.27	20-55-20	8.23	4.93	20-45-20	5.77

[1]Come up time – Processing time – Cooling time.

Table 3. Influence of oil component on the number of cells *Bacillus subtilis* in canned seafood in oil

Title of canned seafood	Number of cells *Bacillus subtilis* in 1 g of product content		
	Before sterilization	After sterilization	
		Control	Experimental
Smoked surf clam in oil	$2.46 \times 10^2 \pm 1.8 \times 10$	9.0 ± 4	0
Smoked mixed seafood in oil	$3.20 \times 10^2 \pm 2.7 \times 10$	13 ± 4	0
Smoked sea cucumber in oil	$1.09 \times 10^2 \pm 0.8 \times 10$	7.0 ± 3	0

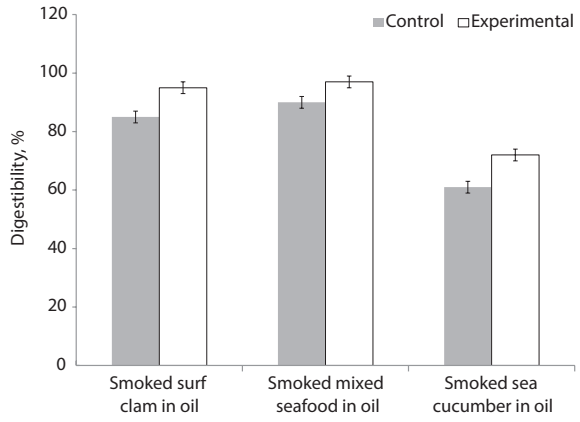

Fig. 1. Digestibility of the protein component contained in the control (vegetable oil) and experimental (spice-oil extracts) samples.

Dutova et al. (1976), Mazokhina-Porshnyakova et al. (1977) and Syromyatnikova (1964) noted that parts of the spore-forming cells of *Bacillus subtilis (B. subtilis*) in canned seafood survived sterilization and remained viable throughout the term of storage. The presence of bacilli, even in their resting state, affects the quality of canned food and leads to the "aging" of protein products. According to the rules and norms of sanitization, *B. subtilis* are permitted as "residual" microflora in sterilized canned seafood, but their abundance therein must not exceed 11 cells per 1 gram of product. Thus, the number of *B. subtilis* cells in the canned seafood with spice-oil extract was determined before and after sterilization. Table 3 shows that, before sterilization, the total number of bacilli averaged 320 ± 64 cells per 1 g of product, while after sterilization, the numbers of mesophilic aerobic and facultative anaerobic microorganisms in the experimental samples were equal to 0, meaning that they were industrially sterile. Viable cells of *B. subtilis* remained in the control samples at lower counts after sterilization, but *B. subtilis* was not detected in the spice-oil extract samples (Table 3).

One of the indicators of the degree of the preservation of nutritional value during the sterilization process is the thermal damage of proteins, which affects their digestibility. To assess the effects of spice-oil extract and sterilization modes on the digestibility of proteins, biotesting was carried out. Fig. 1 presents the protein digestibility of the experimental and control samples of canned seafood before and after sterilization. The replacement of vegetable oil by spice-oil extract was accompanied by an increase in accessibility of the canned seafood protein component, with a 10.1% increase in smoked surf clams, an 8.5% increase in smoked mixed seafood and an 8.6% increase in smoked sea cucumber. It is possible that the minor fat-soluble components of spices have a direct positive effect on the digestibility of the proteins contained in seafood canned with spice-oil extract.

Fatty acids are destroyed during thermal processing (Brazhnikov, 1987; Gelfand, 1994). The influence of spice-oil extract on the persistence of the lipid component in canned seafood was estimated by comparing the fatty acid compositions of control and experimental samples of the sterilized products. The oil fraction of canned seafood, which had been stored for 30 days after manufacture, was used to evaluate fatty acid composition.

The fatty acid compositions of canned seafood with various vegetable oils or with their mixture (control) and with spice-oil extract (experimental) are summarized in Table 4.

The results indicated differences in the fatty acid contents of oils from the control and experimental samples. The

Table 4. Comparative characteristics of fatty acid composition in canned seafood

Used oil	Sum of fatty acids (% of total fatty acids) in the samples of canned seafood					
	Control			Experimental		
	1	2	3	1	2	3
Smoked surf clam in oil						
Corn	17.2 ± 0.2	27.6 ± 0.1	55.2 ± 0.2	14.9 ± 0.1	26.7 ± 0.1	58.4 ± 0.2
Sunflower	17.5 ± 0.1	26.4 ± 0.3	56.1 ± 0.2	14.0 ± 0.1	25.6 ± 0.3	61.1 ± 0.1
Smoked mixed seafood in oil						
Soybean	20.8 ± 0.3	25.5 ± 0.1	55.7 ± 0.2	16.6 ± 0.1	22.1 ± 0.3	61.3 ± 0.1
Mixture of soybean and corn oils (55:45)	16.5 ± 0.1	25.7 ± 0.2	57.8 ± 0.2	15.9 ± 0.3	24.6 ± 0.1	59.5 ± 0.2
Mixture of soybean and sunflower oils (60:40)	17.6 ± 0.3	24.1 ± 0.2	8.3 ± 0.1	16.2 ± 0.3	23.7 ± 0.3	60.1 ± 0.1
Smoked sea cucumber in oil						
Olive	21.0 ± 0.4	16.3 ± 0.3	62.7 ± 0.2	17.2 ± 0.2	12.5 ± 0.1	70.3 ± 0.4
Sunflower	21.7 ± 0.2	26.1 ± 0.2	25.2 ± 0.1	16.8 ± 0.4	24.9 ± 0.3	58.3 ± 0.3
Mixture of soybean and sunflower oils (60:40)	21.2 ± 0.1	24.5 ± 0.2	54.3 ± 0.2	17.6 ± 0.3	23.4 ± 0.1	59.0 ± 0.2

Note: 1, Saturated fatty acids; 2, Monounsaturated fatty acid; 3, Polyunsaturated fatty acids.
Values are the means ± standard deviation of three determination.

amount of polyunsaturated fatty acids in canned seafood with added spice-oil extract was significantly higher than that in all assortments of canned goods with added vegetable oils. This suggests that the longer duration of sterilization necessary for the control samples alters the fatty acid composition of oils. Fatty acids with shorter carbon chains are formed during the destruction of fatty acids.

The destructive changes in the fatty acid composition of the oil component increased with increasing temperature treatment duration. The thermal processing of canned seafood at 115°C for an additional 5 min led to the destruction of polyunsaturated fatty acids in canned goods (corn oil, 5.5%; sunflower oil, 8.2%; soybean oil, 9.1%) (Table 4).

Destruction of polyunsaturated fatty acids was greater in the oils of control samples compared to experimental samples (smoked sea cucumber in oil); e.g., sunflower oil (10.5%) and olive oil (10.8%).

The blending of oils promotes an increase in the resistance of the oil components of canned seafood against the action of heat during sterilization, especially when spice-oil extract is used. In seafood canned with a blend of soybean oil and corn oil (55:45) and sterilized for an additional 5 min, the polyunsaturated fatty acid content was reduced by 2.9% compared to that in goods canned with the spice-oil extract. The 10-min reduction in the sterilization duration of seafood canned with an oil mixture or with spice-oil extract promotes the preservation of polyunsaturated fatty acids by 8% compared to goods canned with vegetable oil.

In conclusion, in the manufacture of canned seafood, the substitution of spice-oil extract for vegetable oil reduces the heat resistance of microbial spores, hence enabling effective sterilization of canned goods at 115°C for a shorter period of time, that is, by 5 to 10 min for canned goods with added spice-oil extract. This 5-10-min reduction in the duration of sterilization at 115°C of goods canned with spice-oil extract can reduce thermal damage to the major constituent nutrients while maintaining the digestibility of the protein component.

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