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Original article

# Optimizing Heat Treatment for Quality Enhancement of Canned Pea Sauce Dishes

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**Abstract**

As lifestyles continue to evolve, the demand for canned foods, particularly in collective catering, has seen a notable surge. Traditional recipes, including the beloved Tunisian dish of pea sauce, are increasingly sought in canned formats. This study aimed to develop a canned pea sauce recipe and optimize its sterilization parameters. The formulation of the pea sauce involved considerations of factors influencing sensory quality, such as the pre-cooking time of the meat, the amount of tomato paste, and the spice mixture. To assess the sterilization process, two scales were tested: scale 1 (115°C for 60 min) and scale 2 (115°C for 45 min). Stability tests were carried out, and sterilization values were determined using the Biglow method. Various parameters, including pH, peroxide index, total volatile basic nitrogen (TVBN), and titrable acid values, were determined in conjunction with sensory evaluation comparing the final product under both thermal scales.The optimal recipe parameters were identified as a pre-cooking time of 6 minutes, 14 grams of tomato paste, and 7.60 grams of the spice mixture. Both the two scales were validated, yielding sterilizing values of 9.9 min and 8.3 min for scale 1 and scale 2, respectively. Stability tests of the optimized canned pea sauce showed satisfactory results for the two thermal scales. However, scale 2 exhibited slight improvements in pH, peroxide index, TVBN, titratable acidity, and various organoleptic parameters compared to scale 1.These findings contribute to the formulation of an optimized canned pea sauce recipe with enhanced stability and sensory attributes, addressing the increasing need for convenient food options in contemporary lifestyles, particularly in shared catering environments.

**Keywords:** Canned Pea Sauce, Quality, Sterilization, Stability, Traditional Recipes.

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## INTRODUCTION

Throughout the course of human civilization, the imperative of preserving food has evolved from a basic necessity to a crucial practice for maintaining sanitary standards and preventing contamination (Tadini & Gut, 2022). Contemporary food preservation techniques have advanced significantly beyond the rudimentary methods of in the past, underscoring the importance of understanding the the procedures employed in the modern food preservation industry (Chiozzi et al., 2022). The application of heat processing is pervasive in the food industry (Tola & Ramaswamy, 2018; Tadini & Gut, 2022). This conventional thermal processing not only ensures microbioligical stability and food conservation but also eradicates pathogen spoilage (Dornoush & Bagher, 2022). Since the inception of heat processing in 1810, extensive research studies and scientific applications have been conducted to enhance sterilization efficiency and food quality. With food security emerging as a pressing global concern, consumers are increasingly conscientious about the safety and health aspects of their food choices (Chiozzi et al., 2022).

Furthermore, changing consumer nutritional behaviors over the past decate have witnessed a pronounced preference for quick and ready-to-eat foods, mirroring the rapid urbanization of the world (Tadini & Gut, 2022). The thermal canning of food necessitates adherence to an effective sterilization regimen at precisely defined temperature and durations (Dornoush & Bagher, 2022). In the production of new canned foods, optimizing thermal processing becomes imperative to minimize the deterioration of essential quality characteristics and to attain the desired shelf life by eliminating spoilage bacteria (Chiozzi et al., 2022). The control of food quality is paramount throughout the production process and storage duration, with a particular emphasis on ensuring physico-chemical and microbiological stability, as well as employing proper cooking methods to safeguard food security (Singh & Ramaswamy, 2023). Canning process required hermetically sealed containers and precise thermal programs. These programs not only thwart the proliferation of bacteria under normal non-refrigerated conditions but also to neutralize toxins, enzymes, and other bacterial products (Haouet et al., 2018; Mansour et al., 2023). The temperature and duration of the thermal process are contingent on the initial pH value of the product. Indeed, acid or acidified products with pH <4.5 are sterilized under 100°C i.e pasteurization. In the other case, low acid products with pH>4.5 necessitate sterilization at temperatures exceeding 100°C (Boix et al., 2022).

The heat processing for sterilization specifically targets the destruction of C*lostridium botulinum*, a critical pathogen in low acid products. Adhering to the rule of 12 decimal reductions (12D) during the thermal process guarantees the total inactivation of *C. botulinum*, where the D value represents the time needed to eliminate 90% of total pathogens (Soni et al., 2022). Usually, the sterilizing value is calculated using the evolution of the core temperature of the product at the coldest point of the product (Soni et al., 2022). Nowadays, canned foods constitute the main component of the individual ration in developed countries given its safety, easy preparation, long shelf-life, and preservation of natural sensory attributes of food (Singh & Ramaswamy, 2023). Indeed, agri-food companies looking for improving tasting and palatability, the recipe of canned food is inspired from authentic kitchen. Consequently, canned food recipes mirror local customs, food culture, and ecological characteristics of each country and region (Mardatillah, 2020). In line with this, our study focused ~~focuses~~ on canning a pea sauce, a traditional Tunisian recipe and one of the most preferred dishes in Tunisia. This study endeavoured to enhance the pea sauce recipe by fine-tuning ingredients and cooking methods, to validate the canning scale for optimal sterilization, and to rigorously evaluate the long-term quality and stability of the canned pea sauce, addressing both sensory and safety considerations. Through this approach, we aimed to contribute valuable insights to the culinary and food preservation fields.

## MATERIALS and METHODS

### Canned pea sauce preparation

The traditional Tunisian dish "pea sauce" is a classic pea sauce made by cooking onions in olive oil, then adding fresh peas, tomatoes, and local spices such as cumin, coriander, and paprika. Tender pieces of lamb are incorporated, and the sauce is simmered slowly until the flavors meld and the peas are tender. In this study, the canned pea sauce was prepared in a canned food industry, it is based on chicken meat, green pepper, onion, vegetable oil, paste, potato, salt, starch and the spices mixture, hot pepper, black pepper, turmeric, caraway. The chicken steak pieces were pre-cooked in vegetable oil at 90°C during 3 minutes. The peas were placed in blanching tanks at a temperature of 95°C during 10 min and then it is immediately put into ice-filled trays in order to stop the proliferation of micro-organisms. Then, the sauce was cooked at 90°C during 30 minutes at the same day of filling in order to preserve sensorial and nutritional properties, and avoid oxidation of the product as a whole. Afterwards, the trays are filled by assembling the pre-prepared sauce, peas and sauted meat in packaging cans. Cans were firstly filled with meat, pea and then with the sauce at 80°C before being crimped. Finally, once out of the autoclave the cans are ready to be properly labeled, stored and transported to the food market (Figures 1 and 2).

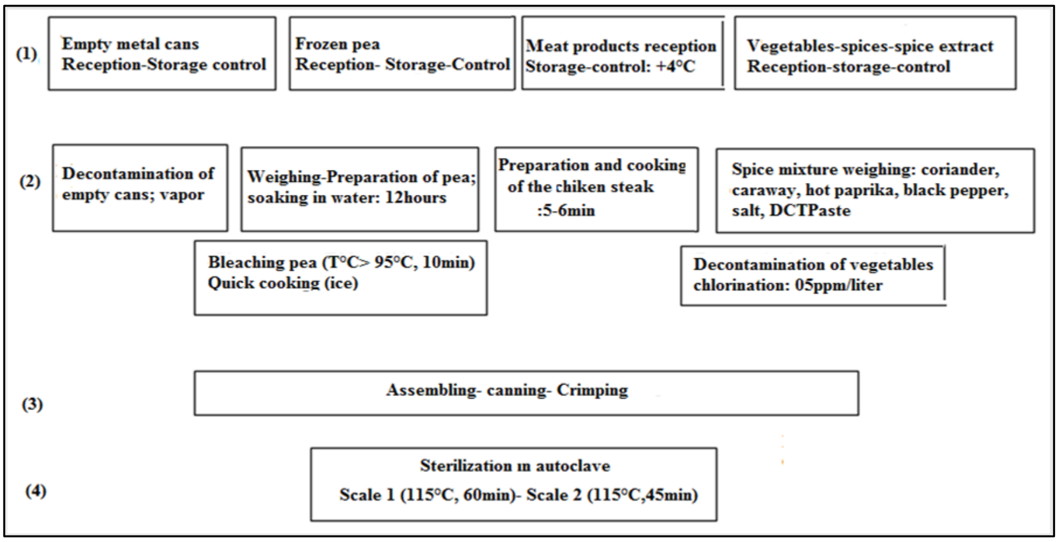



**Figure 1.** Different steps of preparing the canned pea sauce

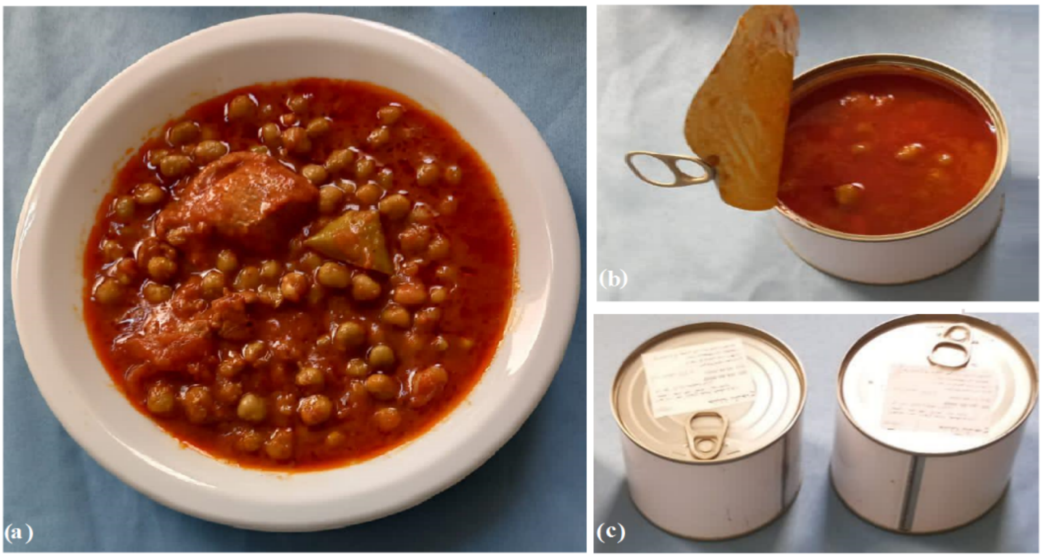



**Figure 2.** Final Product of Canned Pea Sauce: (a) Pea Sauce with Chicken Meat; (b) Pea Sauce Filled in Cans; (c) Final Crimped Cans

### Optimization of the recipe formulation

#### *High and low Level of fixation*

In order to optimize the pea sauce formulation and its preparation process, parameters of quantity of spices and tomato-paste and the pre-cooking time of chiken meat were modulated. Before beginning, it is primordial to determine the low and high levels of these three chosen factors. For this reason, a serie of 12 assays were realized in order to determine the high and low levels of each factor. For this, four different values were recorded for each factor and the assigned value was chosen according to Abdelaali et al. (2024) and according to manufacturer's recommendations while the other factors still fixed (Table

1). Each one assay of 12 preliminary experiments corresponds to a differet recipe of canned pea sterilized at 115°C during 60 min. These 12 cooked and canned recipes are considered as the samples to undergo sensorial evaluation by a panel with 12 trained evaluators. The panel assign a score from 1 to 4 for each sample, with the score 1 corresponding to the most preferred dish and the score 4 indicating the least preferred dish. Thus, each note is attributed only once. The global ranking of the samples is done by calculating the sum of the marks attributed by all the tasters. The dish with the lowest score is ranked as the best requested dish and vice versa (Table 1).

**Table 1.** High and low level of fixation of tomato Paste, spices and pre-cooking meat

| Test N°. | Quantity of tomato Paste (g) | Quantity of spices (g) | Pre-cooking meat time (min) | Overall score given by tasters | Acceptability ranking |
|---|---|---|---|---|---|
| A | 14 | 7.29 | 3 | 20 | 1 |
| B | 15 | 7.29 | 3 | 33 | 2 |
| C | 16 | 7.29 | 3 | 45 | 3 |
| D | 17 | 7.29 | 3 | 52 | 4 |
| E | 18 | 7.60 | 3 | 21 | 1 |
| F | 18 | 7.91 | 3 | 32 | 2 |
| G | 18 | 8.22 | 3 | 42 | 3 |
| H | 18 | 8.53 | 3 | 53 | 4 |
| I | 18 | 7.29 | 3 | 53 | 4 |
| J | 18 | 7.29 | 4 | 41 | 3 |
| K | 18 | 7.29 | 5 | 29 | 2 |
| L | 18 | 7.29 | 6 | 27 | 1 |

### Experimental design

After the fixation of low and high level of spices and tomato-paste quantities and the pre-cooking time of chiken meat, a complete factorial design was realized. For this, series of eight experiments were realized using only two values which correspond to low and high levels of three tried parameters chosen and fixed in previous paragraph such as showed (Table 2).

These 8 cooked and canned recipes are considered as the samples to undergo sensorial evaluation (Table 2). This factorial design is followed by a sensory analysis using a trained panel of 12 tasters in order to select the optimum recipe (Table 2). Thus, the value (-1) was assigned to the low level and (+1) to the high level of each factor. The result of factorial design was analyzed through a panel of tasters in order to determine difference between the samples about organoleptic criterias including the color, the smell, the taste, the texture of the meat, as well as the potential Hydrogen (pH) were registred according to the experimental design. Minitab (version 2019) was used to analyze the factorial design data and assess differences in organoleptic criteria and pH levels among the samples.

**Table 2.** Experimental factorial design to determine the optimal pea sauce recipe

| Recipe N° | Tomato-Paste (g) | Quantity of Spices (g) | Cooking meat time (min) |
|---|---|---|---|
| 1 | - | - | - |
| 2 | + | - | - |
| 3 | - | + | - |
| 4 | + | + | - |
| 5 | - | - | + |
| 6 | + | - | + |
| 7 | - | + | + |
| 8 | + | + | + |
| Low level (-) | 14 | 7.60 | 5 |
| High level (+) | 15 | 7.91 | 6 |

**Determination of the sterilization values**

For validation of the sterilization value, two sterilizing scales were tried on the optimal recipe of pea sauce.The first scale (1) used a temperature of 115°C during 60 min. However, the second scale (2) applied the same temperature but during 45min. These scales respected the required temperature of sterilization wich must be more than 100°C (Boix et al., 2022).

Canned  meat, vegetables and ready meals with a pH >4.5 must be sterilised to ensure long-term preservation. *Clostridium botulinum* stands as the benchmark microorganism for resistance, recognized as the reference pathogen in microbial studies (Munir et al., 2023). The food safety criterion is heat treatment, which is capable of achieving 12 decimal reductions in the population of *C. botulinum* spores per gram of product (Boix et al., 2022).The efficiency of cans sterilization was evaluated through meaningfull associations between heating temperature, time and the lethal rate of the target bacterial flora (Chiozzi et al., 2022).

The Bigelow method, applied to assess the tested sterilizing programs, is a thermal processing method applicable to different food technology systems (Giannakourou et al., 2021).The sterilizing value F0 of the prepared canned pea sauce was determined by measuring the core and/or the cold spot temperature of the final product during the thermal cycling using a thermobutton (Plug & Track by Proges Plus, Sopac, France). The total sterilisation value was calculated as the sum of other partial sterilising values according to the following equation:$F0 = \sum_{i=0}^{n} 10^{(T-Tref)/Z} * \Delta ti$ (Eq 1), with T is the product core temperature, and Z factor is the temperature rise that allows to divide by 10 the heating time or the decimal reduction time D wich corresponds to time required to eliminate 90% of micro-organisms from a food at temperature T(Wang et al., 2023).

The sterilizing scales depend on pH value of canned food, which is commonly low acid and did not allow the development of anaerobic bacteria in particular *C. botulinum*, with Z= 10°C, and Tref is

121.1°C. The sterilizing value F0 is an integrated value that derived from the following formula: F0= $\int_0^t 10^{(T-Tref)/Z}.dt$ (Eq2); whith t is the heat treatment time to reach F0 (Jarosz et al., 2022).

**Stability test**

The prepared cans of pea sauce were incubated simutaneously at ambient temperature, 37°C and 55°C for 7 days (NFV08-408, 1997). The product is considered as stable if there are no deformations or leakage on the packaging and absence of significant changes of the odor, color and/ or texture of the product. Differences of measured pH values between ambient, 37°C and 55°C of incubated samples must be less than 0.5 pH units. The incubation of canned foods at 55°C is used as a hygienic indicator and as a decisive criterion for exportation to hot-climate regions as required by some national and European standards (NFV08-408, 1997).

**Physico-chemical parameters**

***pH and acidity***

The pH of the prepared samples was measured using a calibrated electronic pH-meter (HANNA instruments, Romania) according to (NFV08-409, 1997). To take the measurement, the pH meter electrode is immersed in a beaker containing the cooked dish. Before each use, the pH meter is calibrated using two buffer solutions at pH 4 and 7.

The titratable acidity was determined by referring to the standard (NFV05-101., 1974). Acidity is measured using a 0.1N NaOH solution in the presence of a phenolphthalein color indicator. The predominant acid in preserves is citric acid monohydrate, which is used to express results as grams per 100 grams of pea sauce.

**Peroxide value**

Samples of pea sauce cans were also subjected to Peroxide value determination based on the standard (NT118.22, 2002). The tested portion or extracted fat (1g) was treated in a mixed solution by acetic acid and a suitable organic solvent in presence of low concentration of potassium iodide solution (0,1 N). The liberated iodine was titrated using a standard sodium thiosulfate solution (0.1N).The peroxide value is expressed in milliequivalents of active oxygen per Kg of fat according to equation (1) $PV = \frac{(V1-V2)\times N\times 1000}{W}$.

where:

V1 = volume of sodium thiosulfate solution used for the sample (mL).

V2 = volume of sodium thiosulfate solution used for the blank (mL).

N = normality of the sodium thiosulfate solution.

W = weight of the fat sample (g).

**Total Volatil Basic Nitrogen**

The Total Volatile Basic Nitrogen was determined by referring to (EC2074, 2005). The first step consists in deproteinizing the sample with perchloric acid (HClO4) followed by a distillation and neutralization of the acid extract with steam. Finally, the TVBN content is obtained by a titration step with hydrochloric acid (HCl). The result is expressed as mg N per 100g based on the following equation (2) $TVBN = \frac{(V1-V2)\times N\times 14\times 100}{W}$.

where

V1 = volume of hydrochloric acid (HCl) used for the sample (mL).

V2 = volume of hydrochloric acid (HCl) used for the blank (mL).

N = normality of the hydrochloric acid solution.

14= molecular weight of nitrogen (mg).

W = weight of the sample (g).

**Sensory analysis**

Sensory qualities of canned products are one of the most important quality attributes that determine the consumer satisfaction based on color, taste, flavor, aroma and texture. A panel of 12-*trained* panelists using the scoring test was planified for the sensory analysis of the canned pea sauce. Organoleptic attributes including color, flavor, odor, viscosity, texture, and acidity were evalutaed for each sample with a rating from 1 to 9. The products obtained from the studied thermal *scales* were evaluated through a scaling test with nine hedonic scale points (ISO4120, 2021). Samples were treated randomly and scores were expressed as the mean standard deviation.

**Statistical analysis**

All parameters involved in the present study were determined in triplicate. Data were statistically analyzed by using the ANOVA procedure of Minitab (version 2019). Duncan's multiple range tests was used to determine significant differences between mean values. Evaluations were based on a significance of p-value $\leq 0.05$.

## RESULTS and DISCUSSION

**Optimization of the recipe formulation**

The recipes E, F, A, B, L and K (Table 1) are the most accepted since they have the lowest sum of the marks from the panel with respective global marks of 21, 32, 20, 33, 27 and 29 (Table 1). The acceptability-ranking test determined the low and high quantities for each component chosen for the reformulation of the ready-cooked pea sauce recipes. The high and low levels of spices, tomato-paste and pre-cooking time of meat used in the present test are (7.6 and 7.91g), (14and 15g) and (5 and 6 min), respectively (Table1).

The setting of high and low levels of the three factors is used in experimental design in order to determine the optimal recipe formulation with three factors called factorial plan. This experimental design contains eight trials or recipes (Table 2). Then the results of panel tasters for assessment quality of the eight experiments are analyized. This statistical analysis showed that the intensity of color of the pea sauce depends significantly on the amount of spices mixture and tomato paste ($p<0.05$). The flavor of the prepared sauce was significantly affected by all three factors, mainly the number of spices ($p=0.007$), the amount of tomato paste and the pre-cooking time of the meat ($p=0.04$). Meaningfull association was noted between the acidity of the sauce and the amount of tomato paste ($p=0.007$). The meat texture was affected significantly by the pre-cooking time of meat ($p=0.035$). The pH depends on pre-cooking time of the meat ($p=0.023$), the amount of spice mixture ($p=0.038$) and of tomato paste concentration ($p=0.05$).

Based on Minitab analyses of optimization and sensory evaluations, the retained optimal recipe formulation is the trial composed of 14 g of tomato paste, 7.60g of spices mixture and 6 minutes of pre-cooking meat time.

The profound influence of food traditions continues to mold regional, ethical and community identities, offering a vivid portrayal of the local cultural and ecological heritage of the region. However, contemporary lifestyles are progressively shifting towards the prevalent reliance on canned food (Angelidi et al., 2021). Moreover, the use of traditional and authentic recipes not only preserves cultural richness but also emerges as a lucrative source of financial income for the manufacter. This financial viability is particularly noteworthy, considering the historical underutilization of this food category in industrial contexts (Mardatillah, 2020).

These findings showed that sensory quality criteria of canned food depends on types of spice, type of heat process and storage (Gómez-Limia et al., 2022). Understanding how and why specific ingredient's functioned and behave synergistically demystifies this and makes product development a science (Rabadán et al., 2020). The findings of this study aligned with prior research; particularly those emphasizing that traditional culinary product are obtained by cooking and adding spices and seasonings.

The heightened preference among consumers for these flavorful products can be attributed to their authentic sensory and organoleptic characteristics (Mardatillah, 2020). Notably, sensory attributes such as texture, flavor, aroma and color, play pivotal roles in influencing consumer choices. In addition, the impact of thermal treatment influences the palatability of canned foods and thereby shaping consumer behavior (Mardatillah, 2020).

**Validation of the sterilization scales**

In this study, Bigelow's method was used to determine the sterilizing values (F0). Thus (F0) were 9.9 min and 8.3 min for the first scale (1) and the second scale (2), respectively.

The obtained sterilizing values are sufficient according to based on the 12D criterion, and considering *C. botulinum* thermal lethality properties i.e.D121,1=0.21 min and Z=10, the cumulative lethality should exceed 12*0.21=2.52 min. Indeed, the canned pea sauce was treated at 115°C which is sufficient to destroy the spores of the reference pathogenic bacteria, *C. botulinum*, and ensure its biological stability at ambient temperature (González Sandoval et al., 2019). The target of determination of sterilsation values for scale 1 and 2 is to ensure of efficiency of thermal processing and to choose the optimal scale in in order to minimize nutrient loss without compromising safety was the major challenge for the food industry (Amit et al., 2017).

Hence, both tested sterilizing scales are validated since the minimum process should be at least severe enough to reduce the population of *C. botulinum* through 12 decimal reductions (Munir et al., 2023). Contrasting chemical treatement with thermal canning emerges as a superior solution to attributes an efficient destruction of micro-organisms including *C. Botulinum* as refrence germ for low acid product. Indeed, chemical treatment may interfere with food and causes several problems of consumer's health such as carcogenic effects of nitrites (Munir et al., 2023). In contrast, thermal processing stands out as the optimal method, safeguarding human health by effectively destroying *C. Botulinum* and eliminating its neurotoxin.

**Stability test**

After seven days of incubation for 37°C and 55°C the two studied sterilizing scales, there were no changes in the organoleptic quality (texture, smell, color) and in the appearance of the package (no deformation, no bulging or leakage). Besides, the pH variation between ambient, 37°C and 55°C did not exceed 0.5 pH units. The examination of the pea sauce dish demonstrated its stability, affirming its suitability for release in the market and consumption by humans (Table 3).

**Table 3.** Stability test applied to the pea sauce cans prepared according to scale 1 and 2.

| | | Incubated cans | | | | | |
|---|---|---|---|---|---|---|---|
| | | Scale 1 | | | Scale 2 | | |
| | | 25°C | 37°C | 55°C | 25°C | 37°C | 55°C |
| Package | Integrety | N | N | N | N | N | N |
| Product | Odor | N | N | N | N | N | N |
| | Color | N | N | N | N | N | N |
| | Texture | N | N | N | N | N | N |
| | Measured pH-value | 5.47 | 5.57 | 5.41 | 5.59 | 5.44 | 5.38 |
| | Difference of pH | -- | 0.10 | 0.06 | -- | 0.15 | 0.21 |

N: Normal

The finding results indicated the microbiological stability of the canned pea sauce treated with two sterilization sacles In the event of food contamination, thermophilic pea spoilage organisms appear to be of environmental origin. With this in mind, rigorous preliminary operations in the recipe, from preparation to crimping, will go a long way to eliminating these organisms (Amit et al., 2017). This was justified by the destruction of spores, which has been the international reference point for low acidic products for almost a century, ensure to guarantee the food safety product propreties (Ramos et al., 2018).

This observed microbiological stability of canned peas in sauce is due to rigorous application of the rules of good hygienic practices as well as the rules of good manufacturing practices throughout the process to minimize microbiological contamination phenomena throughout the process. This control focuses on specific parameters crucial for preserving food, including pH, water activity, and nutrient content and parameters which can favor the contamination of foreigners of food spoilage include relative humidity and temperature (Amit et al., 2017).

**Effect of the heat treatment on physicochemical parameters**

***pH and acidity***

The statistical analysis of the results, as shown in (Table 4), indicated that pH values decreased significantly ($p=0.006$) according to the ANOVA test performed using IBM SPSS Statistics 26. However, the variation in pH values between the two sterilizing scales was not significant ($p>0.05$). Additionally, heat treatment had a significant effect on titratable acidity, ($p=0.003$). Despite this, the difference in titratable acidity between the two sterilizing scales was not significant ($p>0.05$).

**Table 4.** Physicochemical changes in canned pea sauce: pre- and post-canning analysis

| | Before canning | After canning Scale 1 | After canning Scale 2 |
|---|---|---|---|
| pH | 5.61±0.04a | 5.48 ±0.02b | 5.51±0.03b |
| Titrable Acidity (g citric acid / 100g) | 3.13±0.21a | 4.59±0.43b | 4.26±0.28b |
| Peroxides (meqO2/kg) | 3.93±0.15a | 5.93±0.43b | 5.31±0.38b |
| TVBN (mg N/100g) | 8.46±1.11a | 14.56 ±1.16b | 12.33±1.25b |

The letters (a, b) within each line indicate significant differences ($p \leq 0.05$).

The finding results proved that heat treatement lead to the decrease of pH and increase of acidity of the canned sauce. The pH of the final product for both scale 1 and 2 did not exceed 5.51 pH units. This demonstrates the stability of the final product and the absence of bacterial proliferation (Amit et al., 2017). These findings align with the outcomes of numerous studies suggesting that elevated temperatures can result in an increase in the ionic charge within a solution, primarily attributed to the dissociation of molecules (Ajide & English, 2023). This phenomenon is particularly notable for weak acids and bases.

As pH is a measure of the hydrogen ion concentration, a change in the temperature of a solution will be reflected by a subsequent change in pH and acidity. These changes of pH and acidity may be associated to a common phenomenon known as "non-bulging surging", which occurs in carbohydrate-rich canned foods such as pea. The hydrolysis of carbohydrates present in these foods leads to the production of lactic, acetic and oleic acids (Leitzen et al., 2021).

Besides, the sterilization process has increased the acidity and decreased pH values in the same time in the final product through activation of several biochemical reactions such as Maillard reactions which is systematically leading to the decrease of pH (Liu et al., 2020; Bazana et al., 2022). Also, the pH variation observed can be attributed to a more pronounced interaction between the metal packaging and the food. This was also demonstrated in the study of the interaction between the packaging and its contents.

When sauce components come into contact with the metal packaging material, chemical reactions can occur, which have a direct impact on pH (Scutarașu & Trincă, 2023). Hence, the highest sterilizing temperature is intricately linked to the acidification of the medium. Moreover, the process of lipolysis within the lipid fraction contributes to a further escalation in the acidification of the medium, accompanied by the release of acids (Bazana et al., 2022).

***Peroxide value***

Heat treatment used for canning process contributed to a significant increase of the peroxide value ($p=0.001$) from 3.93 ±0.15 meqO2/kg before canning to 5.93 ± 0.43 for scale 1 and 5.31± 0.38 meqO2/kg for scale 2 (Table 4). Peroxide value of pea sauce samples showed no significant differences between the two sterilizing scales ($p>0.05$).

According to current results there is significant increase of the peroxide value, but it did not exceed the normal value (20meqO2/kg) according to EC2568 (1991). Under natural conditions, oxidation reactions spontaneously form a series of chain reactions leading to the accumulation of hydro-peroxides (LOOH). On the other hand, they are strongly accelerated by a rise in temperature, or by the presence of metal ions which react with hydro peroxides already present to form oxidation-initiating radicals (Domínguez et al., 2019). It reflected a progressive alteration of fats through oxidation. This phenomen consists in the attack and destruction of the double bands of polyunsaturated fatty acids which leads to the formation of peroxide (Domínguez et al., 2019).

In addition, the oxidation of fat is caused by the presence of any of the following factors: oxygen, high temperatures, light, oxidizing substances (salt, nitrate) and metals. The application of heat intensifies the degradation processes of fats, primarily characterized by oxidative rancidity and enzymatic hydrolysis. This is evident in the observed elevation in the peroxide value (Amaral et al., 2018).

The most common way by which dietary lipids are oxidised is through heat treatment which is the common methods in food processing; manufacturing and cooking involve the use of high temperatures (Amaral et al., 2018). High temperatures effects on food product fat occur firstly through an oxygen attack on the double bands of the fatty acid chains, which lead to peroxides and hydroperoxides accumulation (Jackson & Penumetcha, 2019). Oxidation is a mechanism that requires the presence of oxygen for this lipid degradation. It may be either naturally present in the product, or coming from the surrounding atmosphere (Domínguez et al., 2019). Also the peroxide value can be affected by some oils used in the food canning industry, such as virgin olive oil or sunflower oil, have been demonstrated to contain natural antioxidants and play a key role in the oxidation process (Zhang et al., 2021).

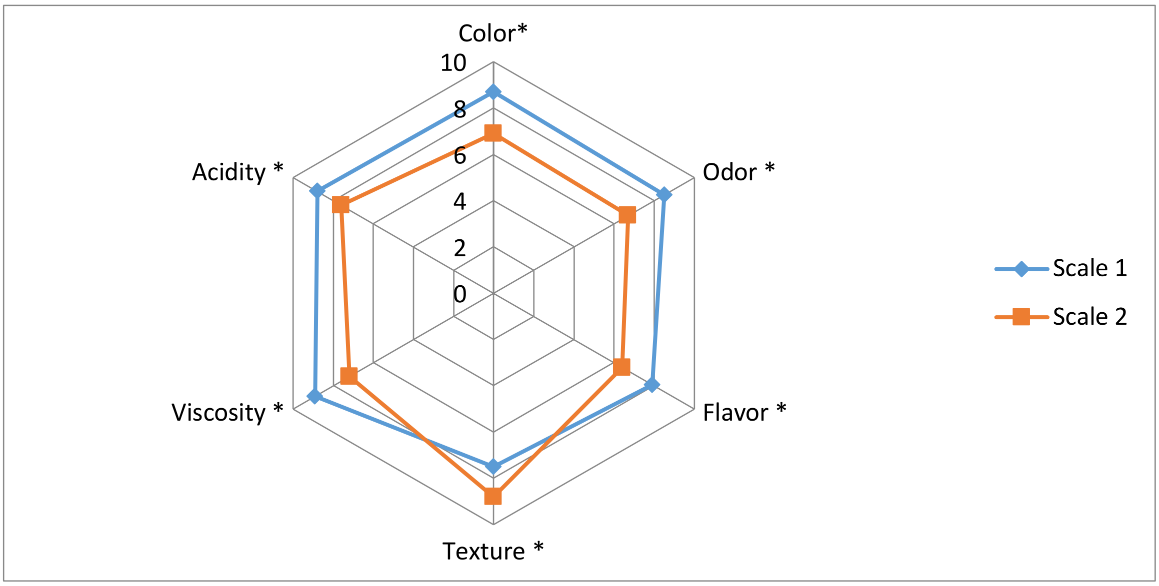
***Total Volatil Basic Nitrogen***

A significant increase of the TVBN amounts was observed in the examined samples after application of the heat treatment ($p<0.05$). It increased from 8.46 ±1.11 mg N/100g before canning to 14.56±1.16 mg N/100g for scale 1 and 12.33 ± 1.25 mg N/100g for the second scale (Table 4). No significant difference was observed regarding the TVBN values of tested samples between the two sterilizing scales.

According to the results of this study, the TVB-N content didn't exceed 15 mg/100g and it considered no spoiled according to (EC1022, 2008) which confirms the preservation of the canned pea quality. The notable increase of TVBN after heat treatment may be explained by the denaturation of proteins that release nitrogenous bases leading to the increase in TVBN content (Bekhit et al., 2021). TVBN contains main elements formed by trimethylamine (TMA), dimethylamine (DMA), ammonia and other compound. Indeed, variation of TVBN is a relatively interesting and informative test regarding protein degradation, bacterial spoilage, and the global stability of the final product (Martin et al., 2023). Excessive thermal processing causes significant hydrolysis of collagen allowing degradation of the meat's protein and accentuation of the Maillard reaction. Thermal processing is often used to facilitate the enzymatic hydrolysis of proteins and can generate chemical reactions affecting several amino acids (carbonyl formation, thiol oxidation and aromatic hydroxylation) leading to protein denaturation and to increase TVBN value (Bekhit et al., 2021). These coumpounds are regarded as key indicators of food quality, and their fluctuations result in significant alterations in both color and flavor (Bekhit et al., 2021).

**Effect of the heat treatment on the sensory quality**

The present study revealed that the organoleptic profiles of the pea sauce samples varied significantly according to the performed heat treatment scales. Organoleptic qualities of the canned pea sauce were evaluated by 12 trained panelists using a nine-point hedonic scale, as shown in Figure 3. This was justified by the significant discrepancy in the organoleptic criteria of the canned dish, in particular the color, odor, flavor, texture, viscosity and acidity ($p<0.05$).




Each parameter followed by * shows significant differnce between scales 1 and 2.

**Figure 3.** Organoleptic profile of canned pea sauce: Scales 1 and 2

The variation in texture results between scale 1 and scale 2, as shown in Figure 3, can be attributed to the amino acid composition and protein structure of the meat and peas, which are significantly altered during heat processing.

Numerous organoleptic characteristics of canned food undergo significant influence from heat treatment (Gavahian et al., 2019; Mansour et al., 2023). Observed variations are due to a non-enzymatic but oxydative reactions and lead to the appearence of brown color on the product surface (Rabadán et al., 2020).

Previous work has demonstrated that the coloring caused by the maillard reaction increases proportionally with the increase in pH values from 3 to 7 (Han et al., 2018). As a result of thermal treatment, a variety of volatile compound, non-enzymatic intermediates, and high molecular weight melanoidin could be produced and that change the odor, color, flavor, and antioxidant properties of the final food products (Shakoor et al., 2022; Mansour et al., 2023).

These parameters are used as an indicator of the intensity of heat treatments and they predict the deterioration resulting from heat exposure (Rabadán et al., 2020). It correlates with other quality factors such as sensory and nutritional characteristics, and it may help to indicate defects (Gavahian et al., 2019). Less thermal processing applied in scale 2 improved flavor preserved-color and essential amino acids and vitamins. Flavor of food can be retained, modified, or, occasionally changed during heat processing, with most of the observed changes occured in the volatile flavor components (Gómez-Limia et al., 2022).

In addition, moderated heating treatment makes the texture tenderer due to proteins protection from denaturation and that led to soft fibers. Moreover, the type of raw material can affect the kinetics of texture softening in heat treatment (Khalid et al., 2023). The effect of cooking method and temperature on these proteins has a major influence on the final texture of the cooked meat, including denaturation, dissociation of myofibrillar proteins, transversal and longitudinal shrinkage of meat fibres, solubilization of connective tissue and water holding capacity of the structural proteins (Ahmed, 2021; Mansour et al., 2023). It is proved that heat solubilization of connective tissue improved meat tenderness, while heat denaturation of myofibrillar proteins generally caused toughening during cooking (ElShehawy & Farag, 2019). Heat treatment at higher temperatures, shorter heat-up times and longer holding times have resulted in a softer texture.

Thus, chewing resistance decreases, but it is the prolonged action of higher temperature that leads to the solubilization (Gavahian et al., 2019). However, the heat treatment had a slight effect on the viscosity of canned food. This is justified by the effect of heat on the denaturation of proteins, starch gelatinization and the softening of fibers (Mansour et al., 2023). Collagen fibers undergo structural changes by undergoing a severe thermal process that degrades and denatures those (Khalid et al., 2023). This phenomenon can be attributed to the impact of heating during sauce preparation, which has the potential to alter the cellular structure, particularly the cell wall structure. The variations in viscosity between the two scales can be elucidated by the fact that heating during sauce preparation may destabilize cellulose, resulting in a decrease in viscosity (Bakshi et al., 2022).

## Conclusion

The study on optimizing heat treatment for canned pea sauce has provided valuable insights into the intricate relationship between processing conditions and product quality. Our experimental approach, which evaluated various recipes and heat treatments, led to the identification of a final optimal formulation: 14 g of tomato paste, 7.60 g of spices, and 6 minutes of pre-cooking. This formulation successfully balanced sensory attributes and nutrient preservation. Validation of the sterilization parameters revealed that processing at 115°C for 45 minutes (scale 2) yielded the most favorable organoleptic results. The analysis of heat treatment effects on key quality indicators (pH, acidity, peroxide value, and TVBN) highlighted the significant impact of thermal processing on both physicochemical and sensory properties. Excessive heat was found to cause undesirable alterations in texture and flavor, emphasizing the necessity for precise control of heat treatment parameters. Overall, this research underscores the importance of optimizing thermal processing conditions to enhance the quality and stability of canned pea sauce, ensuring both microbial safety and high consumer acceptance.

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***Conflicts of Interest***

No potential conflict of interest was declared by the authors

## REFERENCES

Abdelaali, H., Hajji, W., Selmi, R., Mallek, H., Ben Khalifa, I., Bellagha, S., . . . Essid, I. (2024). Assessing the Physiochemical and Sensorial Quality of Pea Sauce Canned in Plastic Trays vs. Metal Cans. *Processes, 12*(8), 1657.

Ahmed, M. (2021). Physico-chemical, microbiological and organoleptic assessment for the stored frozen products of tuna. *JAFE, 2*(1), 6-11.

Ajide, M. T., & English, N. J. (2023). Effect of temperature on the dipole response, structural and dynamical properties of water under external electric fields. *Journal of Molecular Liquids, 389*, 122675.

Amaral, A. B., Silva, M. V. d., & Lannes, S. C. D. S. (2018). Lipid oxidation in meat: mechanisms and protective factors–a review. *J Food Sci Technol, 38*, 1-15.

Amit, S. K., Uddin, M. M., Rahman, R., Islam, S. R., & Khan, M. S. (2017). A review on mechanisms and commercial aspects of food preservation and processing. *Agric. Food Secur, 6*, 1-22.

Angelidi, A. M., Kokkinos, A., Katechaki, E., Ros, E., & Mantzoros, C. S. (2021). Mediterranean diet as a nutritional approach for COVID-19. *Metab.: Clin. Exp, 114*, 154407.

Bakshi, R. A., Aslam, A., Khan, Z. S., Fayaz, S., & Dar, B. (2022). Physiochemical, sensorial, and rheological characteristics of sauce developed from Kashmiri apples: Influence of cultivars and storage conditions. *JFNS, 10*(6), 1685-1693.

Bazana, L. C., Carvalho, Â. R., Mace, M., & Fuentefria, A. M. (2022). The influence of the microwave oven on the production of solid culture medium and quality of microbial growth. *An Acad Bras Cienc, 94*, e20211104.

Bekhit, A. E.-D. A., Holman, B. W., Giteru, S. G., & Hopkins, D. L. (2021). Total volatile basic nitrogen (TVB-N) and its role in meat spoilage: A review. *Trends Food Sci. Technol, 109*, 280-302.

Boix, E., Coroller, L., Couvert, O., Planchon, S., van Vliet, A. H., Brunt, J., . . . Popoff, M. R. (2022). Synergistic interaction between pH and NaCl in the limits of germination and outgrowth of Clostridium sporogenes and Group I Clostridium botulinum vegetative cells and spores after heat treatment. *Food Microbiol, 106*, 104055.

Chiozzi, V., Agriopoulou, S., & Varzakas, T. (2022). Advances, applications, and comparison of thermal (pasteurization, sterilization, and aseptic packaging) against non-thermal (ultrasounds, UV radiation, ozonation, high hydrostatic pressure) technologies in food processing. *Appl. Sci., 12*(4), 2202.

Domínguez, R., Pateiro, M., Gagaoua, M., Barba, F. J., Zhang, W., & Lorenzo, J. M. (2019). A comprehensive review on lipid oxidation in meat and meat products. *Antioxidants, 8*(10), 429. Retrieved from https://mdpi-res.com/d_attachment/antioxidants/antioxidants-08-00429/article_deploy/antioxidants-08-00429.pdf?version=1569401571

Dornoush, J., & Bagher, H. S. M. (2022). Ohmic heating application in food processing: Recent achievements and perspectives. *Foods Raw Mater. , 10*(2), 216-223.

EC1022. (2008). 17 October 2008 amending Regulation (EC) No 2074/2005 as regards the total volatile basic nitrogen (TVB-N) limits. Off. J. Eur. Union 2008, 52, 86–88. In.

EC2074. (2005). 5 December 2005. laying down implementing measures for certain products under Regulation (EC) No 853/2004 of the European Parliament and of the Council and for the organisation of official controls under Regulations (EC) No 854/2004 and (EC) No 882/2004, derogating from Regulation (EC) No 852/2004 and amending Regulations (EC) No 853/2004 and (EC) No 854/2004. In.

EC2568. (1991). of July 11, 1991 C1 on the characteristics of olive oils and olive-pomace oils and on the relevant methods of analysis (OJ L 248, 5.9.1991, p.1). In.

ElShehawy, S. M., & Farag, Z. S. (2019). Safety assessment of some imported canned fish using chemical, microbiological and sensory methods. *Egypt. J. Aquat. Res, 45*(4), 389-394.

Gavahian, M., Tiwari, B. K., Chu, Y.-H., Ting, Y., & Farahnaky, A. (2019). Food texture as affected by ohmic heating: Mechanisms involved, recent findings, benefits, and limitations. *Trends Food Sci. Technol, 86*, 328-339.

Giannakourou, M. C., Saltaouras, K. P., & Stoforos, N. G. (2021). On optimum dynamic temperature profiles for thermal inactivation kinetics determination. *Journal of Food Science, 86*(6), 2172-2193.

Gómez-Limia, L., Carballo, J., Rodríguez-González, M., & Martínez, S. (2022). Impact of the filling medium on the colour and sensory characteristics of canned European eels (Anguilla anguilla L.). *Foods, 11*(8), 1115. Retrieved from https://mdpi-res.com/d_attachment/foods/foods-11-01115/article_deploy/foods-11-01115-v2.pdf?version=1650011651

González Sandoval, D. C., Luna Sosa, B., Martínez-Ávila, G. C. G., Rodríguez Fuentes, H., Avendaño Abarca, V. H., & Rojas, R. (2019). Formulation and characterization of edible films based on organic mucilage from Mexican Opuntia ficus-indica. *Coatings, 9*(8), 506.

Han, J.-R., Yan, J.-N., Sun, S.-G., Tang, Y., Shang, W.-H., Li, A.-T., . . . Zhu, B.-W. (2018). Characteristic antioxidant activity and comprehensive flavor compound profile of scallop (Chlamys farreri) mantle hydrolysates-ribose Maillard reaction products. *Food Chemistry, 261*, 337-347.

Haouet, M. N., Tommasino, M., Mercuri, M. L., Benedetti, F., Di Bella, S., Framboas, M., . . . Altissimi, M. S. (2018). Experimental accelerated shelf life determination of a ready-to-eat processed food. *Ital. J. Food Saf., 7*(4), 6919.

ISO4120. (2021). Sensory analysis - Methodology - Triangular test. In.

Jackson, V., & Penumetcha, M. (2019). Dietary oxidised lipids, health consequences and novel food technologies that thwart food lipid oxidation: an update. *Ital. J. Food Saf., 54*(6), 1981-1988.

Jarosz, A., Grenda, T., Goldsztejn, M., Kozak, B., & Kwiatek, K. (2022). Potential risk of botulinum neurotoxin-producing clostridia occurrence in canned fish. *J. Vet. Res, 66*(4), 605-611. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9945006/pdf/jvetres-66-605.pdf

Khalid, W., Maggiolino, A., Kour, J., Arshad, M. S., Aslam, N., Afzal, M. F., . . . Korma, S. A. (2023). Dynamic alterations in protein, sensory, chemical, and oxidative properties occurring in meat during thermal and non-thermal processing techniques: A comprehensive review. *Front. nutr., 9*, 1057457. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9876618/pdf/fnut-09-1057457.pdf

Leitzen, S., Vogel, M., Steffens, M., Zapf, T., Müller, C. E., & Brandl, M. (2021). Quantification of degradation products formed during heat sterilization of glucose solutions by LC-MS/MS: impact of autoclaving temperature and duration on degradation. *Pharmaceuticals, 14*(11), 1121. Retrieved from https://mdpi-res.com/d_attachment/pharmaceuticals/pharmaceuticals-14-01121/article_deploy/pharmaceuticals-14-01121-v2.pdf?version=1635997811

Liu, X., Xia, B., Hu, L. T., Ni, Z. J., Thakur, K., & Wei, Z. J. (2020). Maillard conjugates and their potential in food and nutritional industries: A review. *Food frontiers, 1*(4), 382-397.

Mansour, H., Majeed, K., & Al-Temimi, W. (2023). Determination of the optimal time for the heat treatment time of local canned river and marine fish products in Basra Governorate, knowledge of microbial analysis and sensory evaluation. *TJABS., 12*, 10-21.

Mardatillah, A. (2020). The enterprise culture heritage of Minangkabau cuisine, West Sumatra of Indonesia as a source of sustainable competitive advantage. *J. Ethn. Foods. , 7*(1), 34.

Martin, D., Joly, C., Dupas-Farrugia, C., Adt, I., Oulahal, N., & Degraeve, P. (2023). Volatilome Analysis and Evolution in the Headspace of Packed Refrigerated Fish. *Foods, 12*(14), 2657. Retrieved from https://mdpi-res.com/d_attachment/foods/foods-12-02657/article_deploy/foods-12-02657.pdf?version=1688982578

Munir, M. T., Mtimet, N., Guillier, L., Meurens, F., Fravalo, P., Federighi, M., & Kooh, P. (2023). Physical treatments to control Clostridium botulinum hazards in food. *Foods, 12*(8), 1580.

NFV05-101. (1974). French standard for determining the titratable acidity of products derived from fruit and vegetables. In.

NFV08-408. (1997). October 1997, p. 1-12, Microbiology of foodstuffs. Stability control of appertised and similar products. In.

NFV08-409. (1997). October 1997, Microbiology of foodstuffs - Determination of the pH of sterilised and similar products. In.

NT118.22. (2002). Registered Tunisian standard relating to fats of animal and vegetable origin for the determination of the peroxide value. In.

Rabadán, A., Triguero, Á., & Gonzalez-Moreno, Á. (2020). Cooperation as the secret ingredient in the recipe to foster internal technological eco-innovation in the agri-food industry. *IJERPH, 17*(7), 2588. Retrieved from https://mdpi-res.com/d_attachment/ijerph/ijerph-17-02588/article_deploy/ijerph-17-02588.pdf?version=1586497707

Ramos, S., Millan, D., Ortiz, L., Alonso, D., & la Torre, G. (2018). Effect of high-pressure thermal sterilization on the inactivation of Geobacillus stearothemophilus spores in ready to eat meals. *Int. J. Eng. Sci., 7*(8), 65-74.

Scutaraşu, E. C., & Trincă, L. C. (2023). Heavy Metals in Foods and Beverages: Global Situation, Health Risks and Reduction Methods. *Foods, 12*(18), 3340.

Shakoor, A., Zhang, C., Xie, J., & Yang, X. (2022). Maillard reaction chemistry in formation of critical intermediates and flavour compounds and their antioxidant properties. *Food Chemistry, 393*, 133416.

Singh, H., & Ramaswamy, H. S. (2023). Thermal Processing of Acidified Vegetables: Effect on Process Time-Temperature, Color and Texture. *Processes, 11*(4), 1272.

Soni, A., Bremer, P., & Brightwell, G. (2022). A Comprehensive Review of Variability in the Thermal Resistance (D-Values) of Food-Borne Pathogens—A Challenge for Thermal Validation Trials. *Foods, 11*(24), 4117. Retrieved from https://mdpi-res.com/d_attachment/foods/foods-11-04117/article_deploy/foods-11-04117-v3.pdf?version=1671702705

Tadini, C. C., & Gut, J. A. (2022). The importance of heating unit operations in the food industry to obtain safe and high-quality products. *Front. nutr., 9*, 853638. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9094675/pdf/fnut-09-853638.pdf

Tola, Y. B., & Ramaswamy, H. S. (2018). Novel processing methods: updates on acidified vegetables thermal processing. *Curr. Opin. Food Sci, 23*, 64-69.

Wang, W., Wu, J., Zheng, J., Wu, Z., Huang, J., Lu, Y., . . . Huang, L. (2023). Simulation and optimization of the thermal sterilization process of puree cans using the production of chestnut puree as an example. *Front. microbiol., 14*, 1135700. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10166203/pdf/fmicb-14-1135700.pdf

Zhang, N., Li, Y., Wen, S., Sun, Y., Chen, J., Gao, Y., . . . Yu, X. (2021). Analytical methods for determining the peroxide value of edible oils: A mini-review. *Food Chemistry, 358*, 129834.