บทความวิจัย

การพัฒนาผลิตภัณฑ์ซุปไหมข้าวโพดพร้อมรับประทานสำหรับผู้สูงอายุและผู้ป่วยโรคไม่ติดต่อเรื้อรัง

ชนิตา อินทาทอง รุ้งดาว กลิ่นจะโป๊ะ สมัชชา กรุงแก้ว วทันยา ไชยสายัณห์ อทิตยา ตันธรรศกุล และ พัชนีย์ ยะสุรินทร์*
ภาควิชาเทคโนโลยีชีวภาพ คณะเทคโนโลยีเทคโนโลยีชีวภาพ มหาวิทยาลัยอัสสัมชัญ

* ผู้นิพนธ์ประสานงาน โทรศัพท์ 08 1645 1312 อีเมล: patchaneeysr@au.edu
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รับเมื่อ 13 กันยายน 2567 แก้ไขเมื่อ 7 ตุลาคม 2567 ตอบรับเมื่อ 15 ตุลาคม 2567 เผยแพร่ออนไลน์ 29 ตุลาคม 2567

บทคัดย่อ

งานวิจัยนี้เป็นการพัฒนาซุปไหมข้าวโพดพร้อมรับประทานสำหรับผู้สูงอายุและผู้ป่วยโรคไม่ติดต่อเรื้อรัง โดยมีวัตถุประสงค์เพื่อแก้ไขปัญหาภาวะขาดโภชนาการของผู้สูงอายุ โดยเฉพาะผู้สูงอายุที่มีโรคไม่ติดต่อเรื้อรัง (NCDs) เช่น โรคความดันโลหิตสูง โรคเบาหวาน โรคหลอดเลือดสมอง และโรคอื่น ๆ ซึ่งเป็นปัจจัยที่ทำให้เกิดปัญหาในการเคี้ยว การกลืน และการได้รับสารอาหารที่ไม่เพียงพอของผู้สูงอายุ โดยผลิตภัณฑ์ซุปไหมข้าวโพดพร้อมรับประทานมีวัตถุดิบหลักและอุดมไปด้วยสารอาหารครบ 5 หมู่ ได้แก่ ใยอาหารจากไหมข้าวโพด คาร์โบไฮเดรตจากข้าวโอ๊ต โปรตีนข้าวกล้องและข้าวกล้องงอก ไขมันจากเนย ผงปรุงรสผัก ผงหัวหอม และพริกไทยบด วัตถุประสงค์หลักของการพัฒนาผลิตภัณฑ์ซุปไหมข้าวโพดพร้อมทาน ได้แก่ การหาปริมาณสัดส่วนที่เหมาะสมของไหมข้าวโพดที่ควรใช้ในสูตร (5%, 10%, 15%) และผงโปรตีนข้าวกล้อง (2%, 4%) และเพื่อศึกษาการยืดอายุการเก็บรักษา ผลิตภัณฑ์ซุปไหมข้าวโพดผ่านกระบวนการฆ่าเชื้อด้วยเครื่องนึ่งฆ่าเชื้อ (Autoclave) ที่อุณหภูมิ 121°C ในเวลาต่างกัน ได้แก่ 15, 20, 25 นาที เพื่อศึกษาระยะเวลาและอุณหภูมิที่เหมาะสมต่อการฆ่าเชื้อและสังเกตการตกตะกอนของซุปไหมข้าวโพด นอกจากนี้คุณค่าทางโภชนาการถูกวิเคราะห์โดยใช้วิธี AOAC International 2023 คุณสมบัติทางกายภาพของผลิตภัณฑ์ เช่น ค่าความเป็นกรด-ด่าง ความหนืด และสีโดยผลิตภัณฑ์ได้รับการทดสอบโดยใช้เครื่องวัดค่าความเป็นกรด-ด่าง (In-house Method WI-TMC-109) การใช้มาตรฐานอาหารสำหรับผู้ป่วยกลืนลำบาก (IDDSI Testing Methods) และเครื่องวัดสี (Hunter Lab, Colorflex-45-2, USA) ตามลำดับ การตรวจวิเคราะห์คุณภาพทางจุลชีววิทยาดำเนินการทดสอบตามประกาศกระทรวงสาธารณสุข ฉบับที่ 355 (พ.ศ. 2556) การประเมินประสาทสัมผัสและการยอมรับจากผู้บริโภคถูกวิเคราะห์โดยใช้โปรแกรม SPSS เวอร์ชั่น 29 จากผลการวิจัยพบว่า สภาวะการทำให้ปลอดเชื้อที่เหมาะสมที่สุด คือ 119°C เป็นเวลา 20 นาที โดยการฆ่าเชื้อด้วยระบบรีทอร์ท (Retort Sterilizer) ซึ่งให้เนื้อสัมผัสที่ดีที่สุดโดยอุณหภูมิและระยะเวลาดังกล่าวช่วยป้องกันการแตกตัวของโปรตีนและการเกิดเจล ซึ่งส่งผลต่อรสสัมผัสของผลิตภัณฑ์ โดยสูตรที่ได้รับความนิยมสูงสุดประกอบด้วยสูตรที่มีไหมข้าวโพด 15% และผงโปรตีนข้าวกล้อง 4% โดยได้รับคะแนนความชอบโดยรวม 7.79 ±1.01 โดยซุปไหมข้าวโพดให้พลังงาน 100 กิโลแคลอรีต่อหนึ่งหน่วยบริโภค (130 กรัม) มีน้ำตาลต่ำ (น้อยกว่า 1 กรัม) และคอเลสเตอรอลต่ำ (5 กรัม) ซึ่งเหมาะสำหรับผู้สูงอายุ นอกจากนี้ซุปไหมข้าวโพดพร้อมรับประทานถูกจัดอยู่ในระดับความหนืดปานกลาง (Level 3) ตามเกณฑ์ IDDSI และผลิตภัณฑ์นี้ยังได้รับการยืนยันว่าปลอดภัยจากเชื้อก่อโรค นวัตกรรมนี้ยังสนับสนุนเกษตรกรไทยโดยการสร้างมูลค่าเพิ่มจากส่วนประกอบข้าวโพดที่ไม่ได้ใช้ประโยชน์อย่างคุ้มค่าและมีส่วนช่วยในการพัฒนาเกษตรกรรมอย่างยั่งยืน

คำสำคัญ: การฆ่าเชื้อด้วยระบบรีทอร์ท การวิเคราะห์คุณภาพทางชีววิทยา สารต้านอนุมูลอิสระ ไหมข้าวโพด อาหารผู้สูงอายุ

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Research Article

Development of Ready-to-Eat Nutritional Corn Silk Soup for The Elderly and NCDs Patients

Chanita Inthathong, Roungdao Klinjapo, Samatcha Krungkaew, Watanya Chaisayan, Attitaya Tandhaskul and Patchanee Yasurin*

Department of Biotechnology, Theophane Venard School of Biotechnology, Assumption University, Bangkok, Thailand

* Corresponding Author, Tel. 08 1645 1312, E–mail: patchaneeysr@au.edu DOI: 10.14416/j.kmutnb.2024.10.019
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Abstract

This research focuses on developing a ready-to-eat corn silk soup aimed at improving nutrition for the elderly and individuals with chronic Non-communicable Diseases (NCDs), such as hypertension, diabetes, and stroke. These conditions often cause difficulties with chewing, swallowing, and maintaining proper nutrition. The primary objectives of the study were to determine the optimal proportions of corn silk (5%, 10%, 15%) and brown rice protein powder (2%, 4%) in the soup formulation, and to explore methods for extending the product's shelf life. The soup was sterilized using an autoclave (First Toy International Co. Ltd., Thailand) at 121°C for varying durations (15, 20, 25 minutes), with observations of texture and precipitation changes. Nutritional analysis was conducted using AOAC International 2023 methods, while physical properties such as pH, viscosity, and color were evaluated using in-house methods (WI-TMC-109), IDDSI Testing Methods, and a colorimeter (Hunter Lab, USA). Microbiological quality was assessed in accordance with the Notification of the Ministry of Public Health No. 355, B.E. 2556 (2013). Sensory evaluation and consumer acceptance were analyzed using SPSS version 29. The optimal sterilization condition was found to be 119°C for 20 minutes using a retort sterilizer, balancing safety with the preservation of nutritional and sensory qualities. This temperature prevented overcooking of delicate proteins and ensured adequate starch gelatinization, resulting in a safe and appealing product for elderly consumers. The soup provides 100 kcal per 130 g serving, with low sugar content (less than 1 g) and cholesterol (5 g), making it suitable for seniors. The preferred formulation, consisting of 15% corn silk and 4% brown rice protein powder, achieved an overall preference score of 7.79 ±1.01. Additionally, the soup is classified as moderately thick (Level 3) according to IDDSI criteria, and microbiological tests confirmed that it is free from harmful pathogens, ensuring its safety for consumption. This innovation also supports Thai farmers by creating economic value from underutilized corn components, contributing to sustainable agricultural development.

Keywords: Antioxidants, Corn Silk, Elderly Food, Microbial Testing, Retort Sterilization

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1. Introduction

Thailand's elderly population is rapidly growing, with over 12 million individuals aged 60 and above as of 2022. This increase, driven by improved healthcare and longer life expectancy, has led to a heightened demand for healthcare services and products tailored to the needs of seniors [1]. According to the Ministry of Public Health, over 9.5 million elderly people are recorded in the health system, many suffering from chronic Non-communicable Diseases (NCDs) such as hypertension, diabetes, and stroke. These health challenges, along with difficulties in chewing, swallowing, and preparing food, contribute to inadequate nutrient intake, negatively impacting their well-being [2]. Dietary fiber is particularly important for seniors, with soluble fiber (from fruits, vegetables, legumes, and oats) helping to lower cholesterol and stabilize blood sugar, and insoluble fiber (from whole grains, nuts, and vegetable skins) promoting healthy digestion. Recommended daily fiber intake for older adults is 28 grams for men and 22 grams for women. Gradually increasing fiber intake helps meet these targets without causing digestive issues [3].

Corn silk, derived from the female flowers of corn (Zea mays), contains approximately 14.82 grams of fiber per 100 grams of the dried powder [4]. Corn silk has a respectable fiber content of 14.82 g/100 g, it is still lower than that of chia seeds and flaxseeds, which are among the highest in fiber content at 34.4 g and 27.3 g per 100 grams, respectively [4], [5]. Other legumes like lentils and black beans also provide substantial fiber but at lower levels than corn silk. There are some advantages and disadvantages of consuming legumes comparing to corn silk [6]. Some elderly individuals may experience digestive discomfort or gas when consuming legumes due to their oligosaccharides, which can be challenging for some people to digest while corn silk contains various bioactive compounds such as flavonoids and phenolic acids, which may offer antioxidant properties and potential health benefits beyond just fiber. Corn silk contains several chemical compounds, including maysin which is a flavonoid with antioxidant properties, anti-inflammatory and anticancer properties [7].

In addition, corn production generates a significant amount of waste, particularly from husks and silk, which are often disposed of improperly, leading to environmental issues like air pollution. Utilizing corn silk for nutritional purposes addresses both health and environmental concerns while adding value to Thailand's agricultural sector [8].

This study aims to develop a ready-to-eat meal replacement using corn silk powder, targeting elderly people and NCD patients. The product is designed to provide essential nutrients in an easily consumable format, offering health benefits such as lowering blood sugar and blood pressure, increasing antioxidant intake, and potentially reducing cancer risks [9]. Additionally, this innovation supports Thai farmers by creating economic value from underutilized corn components, contributing to sustainable agricultural development.

2. Materials and Methods

2.1 Corn Silk Powder Preparation

500 g of corn silk was obtained from the online shop, it was washed with water then it was blanched

at 100°C, for 60 s. The corn silk was dried by using drying machine O.V.D series 10 trays at 60°C for 2 hours. The corn silk was grinded and sieved by using a 100-mesh size sieve to get fine particles of powder. The corn silk powder was packed in the air-tight container for further experiment. The moisture content of corn silk powder was 9.53%

2.2 Ready-to-Eat Nutritional Corn Silk Soup Formulation and Method

The raw materials, sourced from Lemon Farm in Thailand, were combined by softening oats in butter over medium heat, then adding water, corn silk fiber, brown rice protein, and GABA rice. Seasonings (garlic salt, onion powder, black pepper, and parsley) were mixed. The soup was sterilized at 119°C for 20 minutes before undergoing sensory evaluation, nutritional analysis, and consumer testing.

2.3 To Study the Appropriate Ratio of Corn Silk Powder to Develop the RTE Corn Silk Soup

Table 1 Differences percent of corn silk fiber.

Formulation	Percentage of Corn Silk Fiber (%)
A	5
B	10
c	15

Based on the previous studies have incorporated corn silk powder in various food products, such as meat products, with variations of 0%, 1%, 2%, 3%, and 4% corn silk in meatball formulations [10]. For traditional foods, corn silk was used at 5% and 10% alongside wheat flour in Paratha, which increased the total fiber and energy content of the product [11]. In this study, corn silk powder was added at 5%, 10%, and 15% to enhance the fiber content of a soup designed for elderly consumers, improving digestion and offering diuretic benefits [12]. These amounts were selected to help meet the recommended daily fiber intake for individuals aged above 60 [13]. The soup samples were sterilization at 119°C for 20 minutes in a retort sterilizer. A 9-point hedonic scale was applied for sensory analysis, and there were 30 panelists participated in the sensory evaluation [14].

2.4 To Study the Effect of Different Concentrations of Brown Rice Protein Powder on the Sensory Evaluation

The Food and Nutrition Board of the Institute of Medicine recommends that protein should make up about 10%–35% of total energy intake [15]. Brown rice protein powder, offering around 70.59 g of protein per 100 g, is a popular plant-based protein source, especially beneficial for older adults due to its nutritional benefits [16]. Brown rice protein is often used in dietary supplements because of its high protein content, easy digestibility, and suitability for individuals with dairy or soy allergies. Its low glycemic index also helps stabilize blood sugar, making it ideal for seniors at risk of diabetes or insulin resistance [17]. In this study, brown rice protein powder was added to soup formulations at levels of 2% and 4% to boost protein content. A sensory evaluation using a 9-point hedonic scale will be conducted to assess the product's acceptability.

2.5 To Study the Time and Temperature by Using Autoclave Sterilization

Two formulations of soup (2%, 4% of brown rice protein) were sterilized in autoclaves. The samples were sterilized at 121°C at different times (15, 20, and 25 minutes), and their characteristics were observed and recorded.

2.6 To Determine the Nutritional Properties of Ready-to-Eat Nutritional Corn Silk Soup

The samples were processed in accordance with the Thai Food and Drug Administration (FDA) guidelines, as outlined in the Notification of the Ministry of Public Health No. 445 B.E. 2566 (2023) [18]. The nutritional analysis of the Ready-to-Eat (RTE) corn silk soup included measurements of energy, total fat, saturated fat, cholesterol, protein (using a factor of 6.5), total carbohydrates, and total sugars. The analysis was conducted by the Food Quality Assurance Service Center (FQA LAB) at the Institute of Food Research and Product Development (IFRPD), Kasetsart University, Thailand. The specific methods used for analysis are detailed in Table 2.

Table 2 Nutritional of RTE corn silk soup analysis methods.

Analysis Item	Test Method
Energy	Methods of Analysis for Nutrition Labeling (1993) Chapter 6, p.106
Total Fat	In-house method WI-TMC-100 based on AOAC (2023) 2003.05
Saturated fat	In-house method WI-TMC-126 based on AOAC (2023) 996.06, 969.33
Cholesterol	In-house method WI-TMC-125 based on AOAC (2023) 994.10
Protein (factor 6.5)	In-house method WI-TMC-03 based on AOAC (2023) 991.20

Table 2 Nutritional of RTE corn silk soup analysis methods (Continued).

Analysis Item	Test Method
Total carbohydrate	Methods of Analysis for Nutrition Labeling (1993) Chapter 6, p.106
Total sugars	In-house method WI-TMC-07 based on AOAC (2023) 982.14
Sodium	In-house method WI-TMC-19 based on AOAC (2023) 984.27
Potassium	In-house method WI-TMC-133 based on AOAC (2023) 984.27
Ash	AOAC (2023) 923.03
Moisture	AOAC (2023) 925.10

2.7 To Determine the Physical Properties of Ready-to-Eat Nutritional Corn Silk Soup

2.7.1 pH Analysis

The pH value of the sample was determined using the In-house method WI-TMC-109 based on AOAC (2023) 978.18 at Food Quality Assurance Service Center (FQA LAB), IFRPD, Kasetsart University, Thailand. The soup falls under the category of low-acid canned food, which is defined as any food (excluding alcoholic beverages) with a final pH greater than 4.6 and a water activity greater than 0.85 [19].

2.7.2 Viscosity Analysis

According to the method of International Dysphagia Diet Standardization Initiative (IDDSI), the sample was tested by using the 10 ml of syringe. The length of 10 ml scale should be 61.5 mm. The plunger is removed out from the syringe, the nozzle is covered with finger and 10 ml of sample is filled. After that the nozzle is released and start timer. The timer is stop at 10 seconds; the level of the remaining sample is recorded [20].

2.7.3 Color Analysis

The color of flat surface in the center of each sample was determined using a colorimeter (Hunter Lab, Colorflex-45-2, USA). The CIE color values of each sample were reported as L^* (0=black, 100=white), a^*(–a^*=greenness, +a^*=redness) and b^*(–b^*=blueness, +b^*=yellowness). Moreover, the reported L^*, a^* and b^* values were calculated as color difference (ΔE^*) via the following formula:

$$\Delta E^* = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \qquad (1)$$

where L^*, a^* and b^* are values for the samples and L_0, a_0 and b_0 are values for the control [21].

2.8 Evaluation of Microbial Testing of Final Product

Low-acid foods, defined as those with a pH greater than 4.6 and a water activity above 0.85, require specific sterility testing to ensure they are safe for consumption. This testing is crucial because these foods can support the growth of harmful microorganisms, including heat-resistant spores like *Clostridium botulinum*, which can lead to serious health risks if not properly processed [22]. Table 3 displays the shelf-life testing methods to improve the shelf-life of the product. The experiments were done by Food Quality Assurance Service Center (FQA LAB), IFRPD, ISO/IEC 17025, Kasetsart University, Thailand.

2.9 To Study Consumer Acceptance

To determine the customers' acceptance of products, the 9-point hedonic scale is applied. The samples were distributed to the 100 panelists who are at the age more than 50 years old. The panelists were asked to rate the degree of liking for sample raging from 1 (dislike extremely) to 9 (like extremely). The attributes were appearance, smell, viscosity, taste, mouthfeel, aftertaste, and overall liking. The questions consist of four parts: general information, health information, consuming behaviors, and attitudes towards therapeutic food consumption. The data was collected by using google form.

Table 3 Microbial testing methods.

Analysis Item	Test Method
Incubation test at 35°C, 55°C	Compendium of Methods for the Microbiological Examination of Foods, 5th Edition, 2015, (Chapter 61)
Aerobic plate count 35°C	Compendium of Methods for the Microbiological Examination of Foods, 5th Edition, 2015, (Chapter 62)
Aerobic plate count 55°C	Compendium of Methods for the Microbiological Examination of Foods, 5th Edition, 2015, (Chapter 62)
Clostridium botulinum	Compendium of Methods for the Microbiological Examination of Foods, 5th Edition, 2015, (Chapter 32)
Staphylococcus aureus	In-house WI-TM-10 based FDA BAM Online, 2016. (Chapter 12).
Salmonella spp.	ISO 6579–1:2017/Amd.1:2020

2.10 Statistical Analysis

The statistical analysis for sensory evaluation used a Randomized Complete Block Design (RCBD) with subjects as blocks. The data were analyzed by using SPSS software (IBM SPSS Statistics Processor version 29).

3. Result and Discussion

3.1 The Appropriate Ratios of Corn Silk Powder

The experiment was done with three different percentages (treatment) of corn silk powder which are 5%, 10%, and 15%. A 9-point hedonic scale was applied for sensory analysis, and there were 30 panelists participated in the sensory evaluation. The data is shown in Table 4.

The results (Table 4) showed that the formula containing 15% corn silk fiber received the highest overall liking score of 7.27 ±1.4 (P<0.05) and the highest viscosity score of 7.67 ±1.5 (P<0.05), falling into the "Like moderately" category, and meeting the satisfaction of the elderly panelists. While the formula with 10% corn silk powder had the highest taste score of 7.60 ±1.3 (P<0.05), the 15% corn silk powder formula still achieved a higher mouthfeel score of 7.40 ±1.6 (P<0.05), compared to the 10% corn silk powder with score of 6.77 ±1.9 (P<0.05), which was rated "Like slightly." This indicates that most panelists preferred the 15% corn silk powder, as it had the highest overall liking score. Based on the previous study, the corn silk powder with different variations (5% and 10%) were added to the traditional Indian food, Dal, which improve the overall liking acceptability mentioned in section 2.3. Therefore, the 15% corn silk fiber formula was selected for further development.

3.2 Effect of Sterilization Time (at 121°C) and % Brown Rice Protein on Sample Characteristics

To study the optimal sterilization time and temperature of the RTE corn silk soup, the samples were sterilized by using the Autoclave (First Toy International Co Ltd., Thailand).

Based on previous studies, sterilization temperatures typically range from 110°C to 135°C (230°F to 275°F), with 121°C (250°F) being the standard temperature used for various packaging types such as cans, pouches, and bottles. For certainvegetables like radishes, carrots, and potatoes,a temperature of 140°C for 1 minute has been found effective, while other foods may require longer times at different temperatures to ensure proper sterilization [23].

According to the Thai Food and Drug Administration (FDA), sterilizing low-acid foods requires an F_0 value that ensures at least 3 minutes to effectively kill *Clostridium botulinum* spores [24]. In this study, samples were sterilized at 121°C for durations of 15, 20, and 25 minutes.

Table 4 The attributes of the differences percentages of corn silk fiber used.

	Attributes						
% Corn Silk Fiber Used	Appearance	Smell	Viscosity	Taste	Mouthfeel	Aftertaste	Overall Liking
5	7.57 ±1.2^a	7.30 ±1.5^a	6.80 ±1.2^b	7.13 ±1.5^a	6.93 ±1.5^b	7.13 ±1.6^a	6.83 ±1.5^b
10	7.03 ±1.2^a	7.30 ±1.4^a	6.43 ±1.9^b	7.60 ±1.3^a	6.77 ±1.9^b	7.27 ±1.2^a	7.03 ±1.4^a
15	7.03 ±1.2^a	7.00 ±1.6^a	7.67 ±1.5^a	7.47 ±1.5^a	7.40 ±1.6^a	7.23 ±1.2^a	7.27 ±1.4^a

*Values were indicated as a mean ± standard deviation. Value within a column with different superscripts show a significant difference at P<0.05

Table 5 Characteristics of sample after sterilization at different durations.

Characteristics of Sample				
Formulation	**Control**	**15 min**	**20 min**	**25 min**
2% of brown rice protein	 Light in color, less viscosity, and no curding form. Homogenized mixture.	 Darker in color, more viscosity. The curding is formed according to protein denaturation.	 Darker in color, too much viscosity compared to the control. The curding texture is formed.	 Darker in color, too much viscosity compared to 20 mins. The curding texture and brown rice particles are formed.
4% of brown rice protein	 Light in color, less viscosity, and no curding form Homogenized mixture.	 Darker in color, more viscosity and Homogenized texture.	 Darker in color, comparing to the control one. No curding is formed. Homogenized texture.	 Darker in color, more viscosity, and curding form according to heating for a longer time could affect protein denaturation.

Results indicate that the slightly acidic pH of 5.64 in the soup, combined with high temperatures during retort sterilization, can cause protein denaturation through two key mechanisms: Temperature Effect: Higher temperatures increase molecular vibrations, breaking weak bonds like hydrogen bonds within proteins, causing them to unfold and lose their structure. pH Effect: At the slightly acidic pH of 5.64, changes in the charges on amino acids lead to alterations in protein solubility and structure, contributing to denaturation [25]. Moreover, during sterilization, prolonged exposure to high temperatures (121°C for 20 and 25 minutes) causes starch granules in the soup to absorb water and swell, leading to gelatinization, which is critical for soup thickening [26]–[28].

The corn silk soup containing 4% brown rice protein, when sterilized in an autoclave at 121°C for 15 minutes, showed the best texture, with no curdling or protein denaturation. Therefore, the 4% brown rice protein soup formulation was chosen for further studies on the retort sterilization process.

3.3 Preliminary Study of Sterilization by Using Retort Sterilizer

To study the optimal sterilization time and temperature of the RTE corn silk soup, the samples (control, 2% and 4% of brown rice protein) were sterilized at 119°C for 20 min using retort sterilizer (First Toy International Co Ltd., Thailand).

The decision to sterilize corn silk soup containing oat grains, brown rice protein powder, and GABA rice at 119°C for 20 minutes using a retort sterilizer is based on a careful balance between ensuring product safety and preserving nutritional and sensory qualities. Firstly, Clostridium botulinum spores, a primary concern in low-acid foods, require adequate heat treatment to ensure their destruction [29]. While the standard sterilization temperature of 121°C is effective, slightly reducing the temperature to 119°C and increasing the time to 20 minutes can still achieve the required lethality (F_0 value) for safe sterilization [30]. This ensures that all microbial spores, particularly *Clostridium botulinum*, are destroyed without overprocessing the product mentioned in Table 10.

Thai FDA recommends an F_0 value that accounts for both time and temperature, and the combination of 119°C for 20 minutes provides sufficient time at a slightly lower temperature to achieve the same microbial safety. Secondly, higher temperatures can lead to undesirable changes in texture and flavor by selecting 119°C, the risk of overcooking the soup components especially the delicate proteins from brown rice and GABA rice are reduced as the result of 4% brown rice protein, no curding texture is formed [31]. This helps maintain the nutritional profile and sensory attributes of the soup. Thirdly, the combination of ingredients like oat grains and brown rice protein can be sensitive to prolonged high heat [32].

Table 6 Characteristics of sample after sterilization.

Formulation	Control	Temperature and time used Temp 119°C 20 min
2% brown rice protein	 Light color, Homogenized texture, less viscosity. No curding is formed.	 Darker in color, homogenized texture, more viscosity, and presence of curding.
4% of brown rice protein	 Light color, Homogenized texture, less viscosity. No curding is formed.	 Darker in color, homogenized texture, more viscosity, No curding texture, and small brown rice particles are formed.

According to the results in Table 6, the formulation of 4% brown rice protein which sterilized at 119°C for 20 min showed the desirable texture since there is no curding texture, and small brown rice particles are formed. The selected temperature allows for adequate

gelatinization of starches without compromising the overall texture or leading to excessive gelling, which could affect mouthfeel [33]. In summary, sterilizing corn silk soup at 119°C for 20 minutes effectively balances safety, quality preservation, and thermal efficiency, making it an optimal choice for this specific formulation. This approach ensures that the soup remains safe for elderly consumers while retaining its desirable characteristics and nutritional benefits.

3.4 To Determine the Nutritional Properties of Ready-to-Eat nutritional Corn Silk Soup

The nutritional analysis of the soup was conducted using AOAC 2023 methods (Table 2) at the Food Quality Assurance Service Center in Kasetsart University, Thailand

The Food and Nutrition Board (FNB) of the Institute of Medicine (IOM) of the National Academies has released macronutrient guidelines for a prudent diet. Elderly people should get fat 45–65% of energy intake, with reduced intake of cholesterol, saturated fatty acids, and trans fatty acids. Carbohydrates: 45–65% of energy intake, preferably complex carbohydrates in the form of fiber. For adults ≥60 years old, the recommended daily fiber intake is 30 grams for men and 21 grams for women. Protein: 10–35% of total energy intake with an emphasis on lean protein sources to help mitigate muscle loss associated with aging [34]. Based on the final formulation, the RTE corn silk soup provides a balanced nutritional profile suitable for the elderly, with a focus on essential macronutrients and micronutrients [35]. These are the key nutrients per 130 g serving (Table 7) : The soup provides 100 kcal per 130 g, making it a low-calorie option suitable for elderly individuals. The soup's macronutrient profile

Table 7 Nutritional analysis per one serving size.

Analysis	Unit	Result	Calculation	
			Per 1 serving size (130 g)	% RDI (Recommended Dietary Intake)
Energy	kcal/100g	77.39	100	–
Total fat	g/100g	3.11	4	6
Saturated fat	g/100g	1.49	2	10
Cholesterol	mg/100g	5.00	5	2
Protein (factor 6.25)	g/100g	3.28	4	–
Total carbohydrate	g/100g	9.07	12	4
Total sugars	g/100g	0.71	Less than 1	–
Sodium	mg/100g	289.72	380	19
Potassium	mg/100g	63.29	80	2
Ash	g/100g	0.95	–	–
Moisture	g/100g	83.59	–	–

includes 4 g of total fat (4% of RDI), 2 g of saturated fat (2% of RDI), 4 g of protein, and 12 g of carbohydrates per. It is low in cholesterol and sugars, making it a heart-healthy choice. The soup is high in moisture (83.59 g per 100 g), which supports hydration. However, its sodium content is relatively high at 289.72 mg per 100 g (19% of DV), which is important for elderly individuals to consider in maintaining fluid balance and nerve function. The soup also provides 80 g potassium (2% of RDI), essential for regulating blood pressure and heart function. The combination of macronutrients, micronutrients, and low levels of cholesterol and sugars in the RTE corn silk soup makes it a nutritious and balanced option for the elderly population, providing essential nutrients while considering their specific dietary needs and health considerations.

However, this final soup formulation is just the protocol formulation that would be developed in the future. In addition, this product can be claim as a good source of protein based on Thailand Food And Drug Administration (Thai FDA), mentioned the protein content should consists not less than 5 gram per 100 grams of food (Thai FDA, No. 182, 2541) [36].

3.5 To Determine the Physical Properties of Ready-to-Eat Nutritional Corn Silk Soup

The physical properties of the sample before (control) and after sterilization under different conditions—a sample kept at room temperature and chilling temperature—were analyzed, compared, and shown in Table 8. The physical properties, including pH, viscosity, and color of the sample.

Table 8 Physical Properties of sterilized and control sample.

Physical Properties	Control	Sample after Sterilization	
		Sample Kept at Room Temperature	Sample Kept at Chilling Temperature
pH	6.03 ±0.01[a]	5.64 ±0.02[b]	5.62 ±0.07[b]
Color Measurement (CIE Value)			
L^*	48.11 ±0.48[a]	43.32 ±0.08[c]	44.97 ±0.07[b]
a^*	6.83 ±0.15[a]	5.39 ±0.03[b]	5.16 ±0.01[c]
b^*	18.95 ±0.30[c]	20.11 ±0.10[a]	19.76 ±0.13[b]
ΔE^*	–	5.13 ±0.10[a]	3.65 ±0.08[b]

*Values were indicated as a mean ± standard deviation. Value within a column with difference superscripts show a significant difference at $P<0.05$.

3.5.1 pH analysis

The pH analysis of ready-to-eat corn silk soup is crucial for assessing its acidity or alkalinity, which turned affects its safety, flavor, and shelf stability. In this study (Table 8), the pH values of the corn silk soup were measured before and after retort sterilization. Before retort sterilization, the pH value of the corn silk soup was recorded as 6.03 ±0.01, indicating a low acid food. After retort sterilization, the pH value of the soup decreased to 5.64 ±0.02 and 5.62 ±0.02 which were kept at room temperature and chilling temperature, respectively. This reduction in pH indicates an increase in acidity, which can enhance the safety and shelf stability of the product. The decrease in pH may result from the breakdown of certain components in the soup, such as polysaccharides carbohydrates (oat grains, corn silk fiber) and proteins (brown rice), into organic

acids during the heating process. Additionally, the Maillard reaction and other thermal reactions can produce acidic compounds, contributing to the overall acidity of the soup [37], [38]. In summary, the safety pH value of the RTE soup is more than 4.6 reported by Thai FDA Notification no.355 2013.

3.5.2 Color Measurement

The color of corn silk soup before and after sterilization were analyzed using a colorimeter. The results showed that the control (unsterilized) sample was lighter, with a higher L^* value (48.11 ±0.48), and redder, with a higher a^* value (6.83 ±0.15), compared to the sterilized sample (5.39 ±0.0). The sterilized sample had a higher b^* value (20.11 ±0.10), indicating more yellow coloration. The darkening of the soup after sterilization (44.97 ±0.07) is attributed to high temperatures causing the Maillard reaction, caramelization, oxidation of polyphenols, and protein denaturation, leading to the formation of brown pigments and a more intense color due to water evaporation [38].

3.5.3 International Dysphagia Diet Standardization Initiative (IDDSI)

Table 9 The volume of remaining sterilized and control sample

The Volume of Remaining Sample (ml)	Sample after Sterilization		
	Control	Sample Kept at Room Temperature	Sample Kept at Chilling Temperature
	6.67 ±0.15^{c}	9.13 ±0.21^{b}	9.60 ±0.10^{a}

*Values were indicated as a mean ± standard deviation. Value within a column with difference superscripts show a significant difference at $P<0.05$.

The International Dysphagia Diet Standardization Initiative (IDDSI) framework, which categorizes texture-modified foods and thickened liquids into 8 levels, was used to evaluate a 4% brown rice protein sample sterilized at 119°C for 20 minutes. The sample was tested at room temperature (25–30°C) and chilling temperatures (0–5°C) using a 10 ml syringe. The results showed that at room temperature, the sample stopped at 9.13 ml, while at chilling temperatures, it stopped at 9.60 ml. The increase in viscosity observed in corn silk soup at higher temperatures is primarily due to the gelatinization of starches and denaturation of proteins, which together create a thicker, more cohesive mixture [39]. These changes are essential for achieving desired textures in food products like soups, where both flavor and mouthfeel are critical for consumer acceptance. In addition, the ready–to–eat corn silk soup was classified as Level 3 (moderately thick or pureed) according to IDDSI criteria which is suitable for the elderly people who has the difficulty on swallowing.

3.6 Evaluation of Microbial Testing of Final Product

According to Thai FDA Notification No. 355, the Most Probable Number (MPN) analysis requires that Coliform bacteria should be absent or present at less than 3 per 1 gram of food [40]. The analysis results (Table 10) indicate that all tested items are within normal safety parameters. The incubation tests at both 35°C and 55°C returned normal results, suggesting no significant microbial activity. The aerobic plate counts at both temperatures reported no Colony-forming Units (CFU) per milligram, indicating a lack of aerobic bacteria. Additionally,

tests for *Clostridium botulinum* returned negative results, and Staphylococcus aureus was not detected in the sample per 0.1g. Similarly, Salmonella spp. was not detected in the sample, further confirming the absence of harmful pathogens in the tested material. Overall, these results suggest that the sample is microbiologically safe.

Table 10 Microbial testing results.

Analysis Item	Unit	Result
Coliform	/g	Not Detected
Incubation test 35°C, 55°C	–	Normal
Aerobic plate count 35°C	CFU/mg	None
Aerobic plate count 55°C	CFU/mg	None
Clostridium botulinum	/g	Negative
Staphylococcus aureus	/0.1g	Not detected
Salmonella spp.	/25g	Not detected

3.7 Consumers' Acceptance

There were 100 panelists tasted the final formulation. The samples were served at 70°C. 7 attributes using in consumers' acceptance survey which are appearance, smell, viscosity, taste, mouthfeel, aftertaste, and overall liking. 9–hedonic scale was used to determine the degree of liking or acceptance of product. The result shows in Table 11.

Table 11 Consumer's Acceptance score.

Attributes	Score (Mean ±SD.)
Appearance	7.65 ±1.03
Smell	7.73 ±1.08
Viscosity	7.52 ±1.08
Taste	7.54 ±1.15
Mouthfeel	7.61 ±1.18
Aftertaste	7.54 ±1.23
Overall Liking	7.79 ±1.01

According to the result (Table 11), the 100 panelists who are at the age between 40 to 80 years old were tasted the product with the 15% of corn silk and 4 % of brown rice protein. The data showed the results of customers' acceptance of a product based on various factors such as appearance, smell, viscosity, taste, mouthfeel, taste, aftertaste, and overall liking. The result indicated that 15% corn silk fiber and 4% brown rice protein used in the formula had a 7.79 ±1.01 overall liking score. The mean value for each factor ranges from 7.52 to 7.79, indicating that customers generally accept the product positively. The standard deviation values are relatively small, indicating that the data points are close to the mean, which suggests consistency in customers' acceptance.

4. Conclusion

This study successfully developed a Ready-to-Eat (RTE) corn silk soup enriched with corn silk, brown rice protein, oats, and GABA rice, specifically targeting elderly consumers and NCDs Patients. The formulation was evaluated for its nutritional profile, sensory attributes, microbiological safety, and consumer acceptability. The soup provided a balanced nutritional profile, offering 100 kcal per 130 g serving with low cholesterol and sugar content, and high moisture, supporting the hydration needs of theelderly. Its texture was classified as Level 3 (moderately thick/pureed) under the IDDSI framework, making it appropriate for individualswith swallowing difficulties. Additionally, microbiological tests confirmed that the product is safe for consumption, with no harmful pathogensdetected. A consumer panel, comprising

individuals aged 40 to 80, rated the soup with an overall liking score of 7.79, indicating strong acceptance of the sensory attributes. These positive f indings suggest that the corn silk soup is not only nutritious and safe but also well-received by its target demographic. The results of this study offer several benefits and future opportunities for the food industry. By utilizing agricultural raw materials such as corn silk, brown rice, and oats, this product adds value to underutilized crops, creating new revenue streams for farmers and reducing agricultural waste. This approach can be further developed to enhance the use of surplus agricultural resources, promoting sustainability and efficiency within the food industry. Future research could focus on expanding the application of similar formulations to other demographics, improving packaging for extended shelf life, or exploring different flavor profiles to broaden consumer appeal. Overall, this study provides a foundation for further innovation in the development of nutritious, sustainable, and consumer-friendly food products.

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