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The Effect of G/CHNF/ZnONPs Packaging on Nutritional Content, Antibacterial Activity, and Shelf Life of Cheddar Cheese

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***Abstract*—The packaging of food goods is crucial. Due to the presence of packaging, food goods' quality can be preserved while being stored. This research created gelatin-based nanocomposite packaging with the addition of active compounds in the form of CHNF and ZnONPs, which reduced the decrease in the nutritional content of cheddar cheese and increased its shelf life. Cheese is one of the nutrient-rich food products that are susceptible to changes in environmental conditions. The results showed that G/CHNF/ZnONPs films were able to minimize 7.76%, 4.84 %, 13.24%, and 1.78%, respectively, the potential for decreasing levels of protein, fat, carbohydrates, and minerals, especially calcium, during 30 days of storage of unpackaged cheddar cheese. Additionally, the G/CHNF/ZnONPs coating extended the shelf life of cheddar cheese to 131 days, longer than LDPE packaging and without packaging.**

***Keywords*— Food packaging; gelatin film; cheddar cheese; shelf life.**

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I. Introduction

Foods should be packaged to eliminate any chance of breakdown, contamination, or reactivity with packaging materials. Food can be shielded from harm, vibration, temperature, heat, and humidity with proper packing. Packaging serves as a defense against elements like moisture, dust, pollutants, direct contact, and pathogens. These characteristics collectively lengthen the shelf life of food goods. Food is packaged in three different ways: main packaging, secondary packaging, and tertiary packaging. The primary packaging is the primary product's packaging. The outside portion of the primary packaging is known as secondary packaging, and the hard outer covering, known as tertiary packaging, is used for handling, warehouse storage, and transportation/shipping [1]. A crucial component of the system for ensuring food safety is food packaging. One product that needs attention is cheese which is very popular in everyday life because of its nutritional content, such as protein, fat, vitamins, and inorganic salts [2].

Cheese is a well-known food group made from fermented milk in various textures, shapes, and flavors [3]. Packaging is among the crucial steps in cheese manufacture due to the distance between cheese producers and customers. In the modern world, there is a rising need for healthier cuisine. Therefore, cheese packaging primarily shields cheese products from unfavorable environmental factors, mechanical stress, and microbiological decomposition during the transportation and distribution stages [4].

The effectiveness of cheese packaging films and coatings depends on the materials' ability to protect the cheese from mechanical, UV, microbiological, and physical harm while being transported and sold. Coatings and films should be chosen based on the type of cheese (fresh, with a high moisture content, or ripe) and storage circumstances (relative humidity and temperature). Because of the conditions of acidity and high-water content activity, the surface of the cheese is more prone to be contaminated by microorganisms [5]. According to Mei et al. [6], microbial contamination significantly affects cheese storage and shelf-life issues. This microbial contamination occurs because the packaging cannot retain moisture, and no barrier can increase the hardness and organoleptic properties.

Cheese is prone to microbial development or harmful bacteria in the preparation and storage phases. In the food sector, pathogenic bacteria like Listeria monocytogenes (*L.monocytogenes*) and Staphylococcus aureus (S. aureus) are major issues because they pose a serious risk to people, particularly by causing immune system problems. Therefore, to increase cheese's shelf life, packaging must be created that may prevent the growth of dangerous bacteria [7].

Currently, cheese can be protected from oxidation and lipolysis using one of two types of food packaging: modified atmosphere packaging or vacuum packing. However, due to the potential for vacuum packaging to alter the structure and look of cheese and the vulnerability of modified atmosphere packaging to harm from the high levels of carbon dioxide present during transportation, these two packaging types are not commonly utilized in cheese packaging. To prevent the drawbacks above and efficiently maintain the nutritional value of cheese, novel packaging materials with high antioxidant activity are required, along with inexpensive, environmentally friendly, and biodegradable materials [8].

Biodegradable substances such as polysaccharides, lipids, waxes, and proteins constitute the foundation of edible films and coatings. These components can preserve cheese quality, prevent moisture loss, and serve as a semipermeable barrier against moisture, oxygen, and carbon dioxide [9]. In order to extend the shelf life of the product, this type of packaging combines culinary ideas, preservation, and biodegradable, edible packaging, inhibits moisture loss, color fading, lipid oxidation, and deodorizing. The production of biopolymers, which are edible, biodegradable, and can act as transporters of active ingredients, including antimicrobials, antioxidants, flavorings, nutraceuticals, and other chemicals, is a common practice in the food business [10].

The gelatin-nanofiber chitosan film has various active substances, including native plant extracts, antimicrobial agents, and synthetic antioxidants. This coating can lengthen the shelf life of food and enhance its protective qualities [11]. However, the high-water solubility and low tensile strength of gelatin film have limited its applications. As a result, it must be modified by adding active ingredients and combining them with biopolymers to improve its mechanical properties to achieve the desired curing effect [12].

A modified carbohydrate polymer with an average molecular weight of 100–500 kDa, chitosan nanofiber (CHNF), is created by partially deacetylating chitin. Because of its biodegradable qualities, low toxicity, biocompatibility, and strong film-forming capacity, CHNF is frequently utilized in food technology [13].

Gelatin is a naturally occurring biopolymer created when animal collagen is hydrolyzed by an acid or base [13]. It is impossible to produce pure chitosan or gelatin polymers into nanofibers with good nanostructures. To create nanofibers, chitosan, and gelatin must be combined with a few chemically produced polymeric components. Electrospinning can produce nanofibers with good physical qualities by combining chitosan and gelatin [14].

A promising material, zinc oxide nanoparticles (ZnONPs) exhibit photocatalytic and antibacterial properties. Strong antibacterial activity is exhibited by ZnONPs, which are also safer and more biocompatible than AgNPs [15]. Gram-positive (B. cereus, S. aureus, and L. monocytogenes) and gram-negative (*E. coli*, *S. typhimurium*, and *V. parahaemolyticus*) bacteria pathogens can both grow more slowly when ZnONPs are added to nanocomposite films [16].

Making edible films can be done by solvent casting (SC) method. The solvent casting technique is one method that is often used to make films. The solvent-casting process relies on the gelatinization principle and consumes many solvents [17]. Food surfaces may receive edible coatings like a thin edible film. By regulating mass transfer, moisture and oil dispersion, gas permeability (O_2, CO_2), loss of taste and scent, and by retaining mechanical, rheological, color, and aesthetic properties, edible coatings have the potential to increase food quality and lengthen shelf life [18].

G/CHNF/ZnONPs nanocomposite films are anticipated to lengthen the shelf life of food products, particularly in this study's examination of the impact of packaging cheddar cheese with G/CHNF/ZnONPs nanocomposite films made by casting, G/CHNF/ZnONPs nanocomposite films made by coating, LDPE packaging, and both LDPE and cardboard on shelf life, nutritional content (protein, minerals, carbohydrates, and fats), and microbiological.

II. Material and Method

A. Materials

Commercial cowhide gelatin (gel strength 225 g bloom, B-type), CH_3COOH 2%, glycerol (≥99.5%), and polyvinyl alcohol (PVA) purchased from Sigma-Aldrich (Singapore). Chitosan (BCB-Chitin, 99%) was purchased from Shaanxi (China), ZnONPs powder (with mean particle diameter 0f 20-30 nm, 95%) was purchased from Peter ShZhenghou Farm-Reaching Biochemical Co. (Jiangsu, China).

B. Chitosan Nanofiber (CHNF)

CHNF was made using the electrospinning method by mixing 3% chitosan solution and 10% PVA solution in a ratio of 1:2 (v/v). The CHNF solution was made using a magnetic stirrer (Dragonlab MS-H-Pro) at 350 rpm and 50 °C for 120 minutes to dissolve 0.04 grams of CHNF in 2.5 grams of 2% acetic acid.

C. Zinc Oxide Nanoparticles (ZnONPs) Solution Making

The ZnONPs solution was prepared by dissolving 0.03 grams of ZnONPs powder into 2.5 grams of 2% acetic acid using a magnetic stirrer (Dragonlab MS-H-Pro) at 750 rpm and 100 °C for 360 minutes.

D. G/CHNF/ZnONPs Film Making

The packaging was made using the casting knife method with a thickness of 1.4 mm. First, a 4% gelatin solution was made by dissolving 0.02 grams of gelatin into 2 grams of distilled water using a magnetic stirrer (Dragonlab MS-H-Pro) at 350 rpm and 45 °C for 30 minutes. Then, CHNF solution, ZnONPs solution, and glycerol were added. The G/CHNF/ZnONPs solution was put in a sonicator for 30 minutes at a temperature of 30 °C. Next, the G/CHNF/ZnONPs solution was printed onto an acrylic mold and left for 72 hours at room temperature. The film can be applied as cheese packaging.

E. G/CHNF/ZnONPs Making by Dip Coating Method

The prepared film solution that was prepared before is placed in a beaker. The cheese was treated by dipping it into a beaker containing a film solution for 2 minutes. Furthermore, the cheese that had been coated was placed in desiccators with 50% RH for 24 hours. After that, the cheese was stored in the refrigerator for a month and tested for its nutritional content, shelf life, and microbiological properties.

F. Nutrient Content Analysis

Nutrient Content Analysis included protein, fat, carbohydrates, and minerals (calcium). The test was carried out using the Kjeldahl method for protein content, Soxhlet for fat content, Luff Schoorl for carbohydrate content, and AAS for mineral (especially calcium) content.

G. Microbiological Analysis

The *Agar Disk Diffusion* (ADF) method tested the microbiological activity of the bacteria that used *S. aureus, P. aeruginosa,* and *E. coli.*

H. Shelf-life Analysis

The Arrhenius model's ASLT (Accelerated Shelf-Life Testing) approach was used to conduct the shelf-life study.

III. Results and Discussion

A. Protein Content

The cheddar cheese protein content test was carried out using the Kjeldahl method under SNI 01-2891-1992. Among dairy products, cheese has a higher quantity of vital nutrients than it does energy [19]. Cheese contains high biological value protein, ranging from 3–40% depending on the type [19]. In this study, protein levels were tested on cheddar cheese that had been packaged for one month using G/CHNF/ZnONPs nanocomposite film coating method and G/CHNF/ZnONPs nanocomposite film casting method compared with cheddar cheese with LDPE packaging, a combination of LDPE and cardboard packaging, and unpackaged cheddar cheese.

TABLE I
PROTEIN CONTENT DURING ONE-MONTH STORAGE

No	Packaging Types	Protein Content (%)	
		0 day	30 days
1	G/CHNF/ZnONPs film		22.20
2	G/CHNF/ZnONPs coating		22.10
3	LDPE packaging	23.19	21.08
4	LDPE and cardboard packaging		23.04
5	Without packaging		20.30

Table I shows that in the initial conditions, cheddar cheese contained 23.15% protein, whereas, after one month of storage, the protein content decreased to 22.20%, 22.10%, 21.08%, 23.04%, and 20.30%, respectively, for cheddar cheese packaged with G/CHNF/ZnONPs film, G/CHNF/ZnONPs coating, LDPE packaging, a combination of LDPE and cardboard packaging, and without packaging. The decrease in protein content during storage is due to disassembling protein molecules to obtain energy or sulfur for the metabolic reaction [20]. Additionally, the activity of proteolytic bacteria, which may break down protein, might also result in a drop in protein levels. These bacteria can grow optimally at room temperature but can still grow over time at refrigerator temperatures, which can cause protein degradation. The type of packaging used, which is associated with the permeability of the packing, affects the number of proteolytic bacteria identified in food goods [21].

The results showed that the best packaging for maintaining protein content in cheddar cheese was a combination of LDPE and cardboard packaging followed by G/CHNF/ZnONPs film, G/CHNF/ZnONPs coating, LDPE packaging, and without packaging (see Fig.1).

Additionally, it is believed that the presence of secondary packaging in the form of cardboard, which offers additional protection for cheese products, and where the used cardboard has been laminated with a waterproof material to be able to protect the cheddar cheese from the possibility of adding cheddar cheese moisture content, is responsible for the low decrease in protein content in the combination of LDPE and cardboard packaging [22].

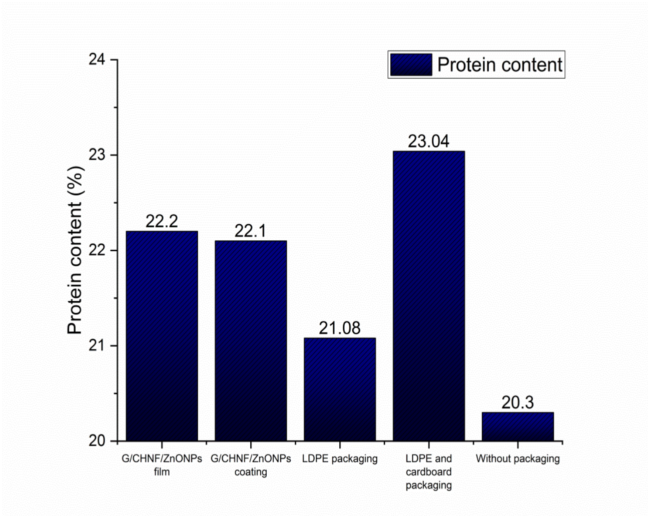

Fig. 1 Protein content of cheddar cheese in various packaging after one-month

From the results obtained, it can also be seen that the G/CHNF/ZnONPs film and coating could minimize 8.19% and 7.76% of the potential decrease in protein levels in cheddar cheese during storage without packaging. This is presumably because the G/CHNF/ZnONPs film and coating have good antimicrobial activity and gas barrier to inhibit the growth of bacteria which can reduce protein levels [23].

B. Fat content

Cheese is a widely favored dairy product due to its nutritional composition. Among the various nutrients found in cheese, fat holds significance. Fat serves essential functions such as safeguarding the body against cold temperatures, acting as a carrier for vitamins A, D, E, and K, shielding vital organs, and generating optimal energy levels, among other roles. This research aimed to assess the impact of packaging on the fat content of cheddar cheese. Specifically, cheddar cheese samples were selected, packaged, and stored in a refrigerator for one month. Subsequently, the fat content of the cheese was examined as part of the study. The fat content was examined using the Soxhlet method under the Indonesian National Standard (SNI) 01-2891-1992. The results of the fat content examination conducted on the cheddar cheese samples are presented in Table II and Fig. 2.

TABLE II
FAT CONTENT DURING ONE-MONTH STORAGE

No	Packaging Types	Fat Content (%)	
		0 day	30 days
1	G/CHNF/ZnONPs film		19.21
2	G/CHNF/ZnONPs coating		19.15
3	LDPE packaging	21.70	19.08
4	LDPE and cardboard packaging		21.02
5	Without packaging		18.10

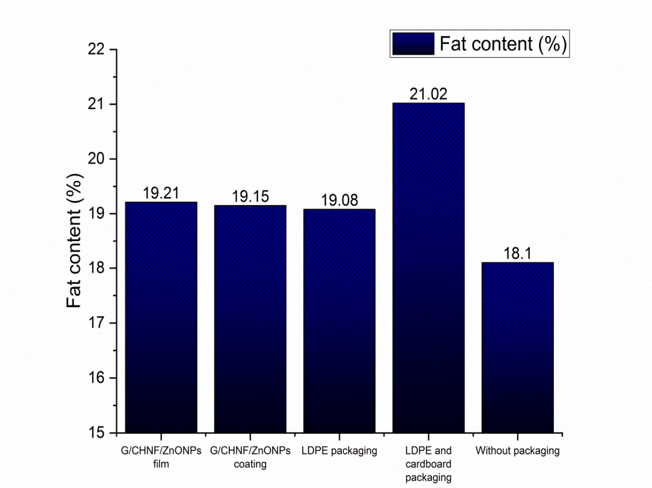

Fig. 2 Fat content of cheddar cheese in various packaging after one-month

Before packaging and storage, the fat content of the cheddar cheese was recorded as 21.70%. However, after being packaged and stored for one month, the fat content exhibited a decrease to 19.21% for samples packaged in G/CHNF/ZnONPs film, 19.15% for samples with G/CHNF/ZnONPs coating, 19.08% for samples packaged in LDPE packaging, 21.01% for samples with a combination of LDPE and cardboard packaging, and 18.10% for samples without any packaging. Based on these results, it is evident that the fat content of the cheddar cheese declines as the storage period prolongs. This observation aligns with the studies conducted by Frau et al [24] and Aini et al. [25] that also highlighted that the fat content of cheese diminishes during storage due to the breakdown of molecular bonds in triglycerides, resulting in the formation of free fatty acids.

Moreover, the degradation of triglyceride molecular bonds leads to a reduction in fat content and an elevation in the content of free fatty acids [24], [25]. The minimal decrease in fat content observed in the cheddar cheese sample with combined LDPE and cardboard packaging can be attributed to the low permeability of the plastic material to O_2 and CO_2. This characteristic effectively mitigates the oxidation of fats by limiting the entry of O_2 from the external environment [26]. Furthermore, the G/CHNF/ZnONPs film and coating exhibit excellent gas barrier properties, effectively minimizing the potential decline in cheddar cheese fat content by 5.12% and 4.48%, respectively, during storage without packaging. This barrier capability helps prevent fat oxidation caused by exposure to oxygen. This corresponds with earlier research indicating that the coated Kilka experienced a smaller fat content decrease than the uncoated Kilka, primarily due to the effective gas barrier provided by the coating [27].

The results also demonstrate that using packaging can mitigate the risk of fat content reduction in cheddar cheese. The test results reveal that the unpackaged cheese samples exhibit the lowest fat content value compared to the other cheese samples after one month of storage.

C. *Carbohydrate Content*

The analysis of carbohydrate content was conducted using the Luff Schoorl method in accordance with the Indonesian National Standard (SNI) 01-2891-1992. The analysis encompassed six samples of cheese that had undergone distinct packaging treatments and were subsequently stored for a duration of one month, as shown in Table 3 and Fig. 3.

TABLE III
CARBOHYDRATE CONTENT DURING ONE-MONTH STORAGE

No	Packaging Types	Carbohydrate Content (%)	
		0 day	30 days
1	G/CHNF/ZnONPs film		12.10
2	G/CHNF/ZnONPs coating		11.92
3	LDPE packaging	13.07	11.68
4	LDPE and cardboard packaging		13.04
5	Without packaging		10.19

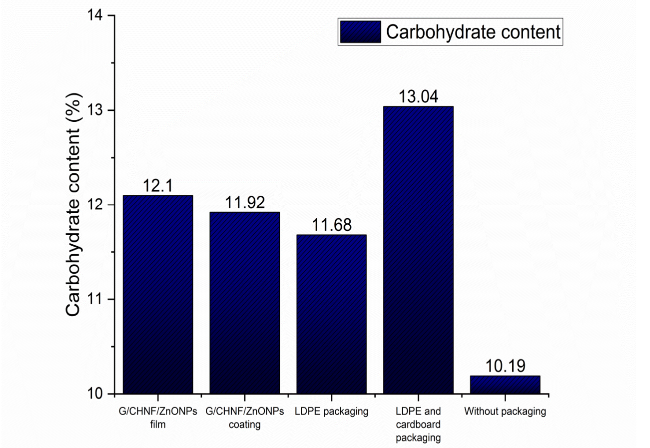

Fig. 3 Carbohydrate content of cheddar cheese in various packaging after one-month

During the carbohydrate content analysis, examinations were conducted both before and after the packaging and storage procedures. Before packaging and storage, the cheddar cheese had a carbohydrate content of 13.07%. After one month, the carbohydrate content in the cheddar cheese decreased, with the most significant decrease observed in the unpackaged cheese, which served as the negative control in this study. After one month of storage, the negative control yielded a carbohydrate content of 10.19%. The most favorable outcomes were observed in cheddar cheese with a combination of LDPE and cardboard packaging, resulting in a carbohydrate content of 13.04%. This was followed by packaging utilizing G/CHNF/ZnONPs film with the casting method, which yielded a carbohydrate content of 12.10%. The G/CHNF/ZnONPs coating resulted in a carbohydrate content of 11.92%, while LDPE packaging recorded a carbohydrate content of 11.68%. The results indicate that implementing packaging successfully prevents the decline of the carbohydrate content in cheddar cheese. The findings underscore the potential of G/CHNF/ZnONPs packaging, whether applied through casting or coating methods, as a viable and effective choice for packaging cheddar cheese. The test results demonstrate that this type of packaging surpasses LDPE packaging and the absence of packaging, establishing its superior ability to preserve the carbohydrate content of the cheese.

Previous studies have established that nanotechnology-based packaging possesses exceptional physical and chemical characteristics while preserving the nutritional content of food. Specifically, when considering carbohydrate content, using nanotechnology ensures food products' safety [28]. This aligns with the research conducted by Ashfaq, Khursheed, Fatima, and Anjum (2022), which confirms that active packaging incorporating nanoparticles serves as excellent packaging material, effectively preserving food quality and maintaining its nutritional value through improved mechanical and barrier properties [29].

D. Mineral (Calcium) Content

Cheese is a dairy product obtained through milk coagulation [30]. Several factors, including the geographical region of milk production, environmental conditions, potential equipment contamination during cheese manufacturing, and more, influence the mineral composition of cheese. Calcium stands out as one of the primary mineral components found in cheese. Previous studies have indicated that the calcium content in cheese tends to decrease over time, with a noticeable decline observed from day 2 to day 90 of storage. Additionally, the decrease in calcium content was more significant in cheese stored in brine than those stored under vacuum conditions [31].

Table IV and Fig. 4 present the outcomes of the mineral content analysis, specifically focusing on calcium, in cheddar cheese subjected to different treatments. Before storage, the initial calcium content of cheddar cheese was recorded as 783.50 mg/100g. However, following a one-month storage period, the calcium content decreased to 764.21 mg/100g for the unpackaged cheddar cheese.

TABLE IV
CALCIUM CONTENT DURING ONE-MONTH STORAGE

No	Packaging Types	Calcium Content (mg/100g)	
		0 day	30 days
1	G/CHNF/ZnONPs film		778.60
2	G/CHNF/ZnONPs coating		778.20
3	LDPE packaging	785.30	774.90
4	LDPE and cardboard packaging		780.30
5	Without packaging		764.21

Throughout the storage duration, the calcium content of the cheese exhibited a decline, reaching values of 778.60 mg/100g, 778.20 mg/100g, 774.90 mg/100g, and 780.30 mg/100g, respectively, for cheddar cheese packaged with G/CHNF/ZnONPs film, G/CHNF/ZnONPs coating, LDPE packaging, and a combination of LDPE and cardboard packaging. The findings revealed that the most effective packaging for preserving the protein content in cheese was a combination of LDPE and cardboard packaging, followed by G/CHNF/ZnONPs film, G/CHNF/ZnONPs coating, LDPE packaging, and unpackaged cheese. Therefore, this indicates that the G/CHNF/ZnONPs nanocomposite film exhibits considerable potential as packaging material for cheddar cheese.

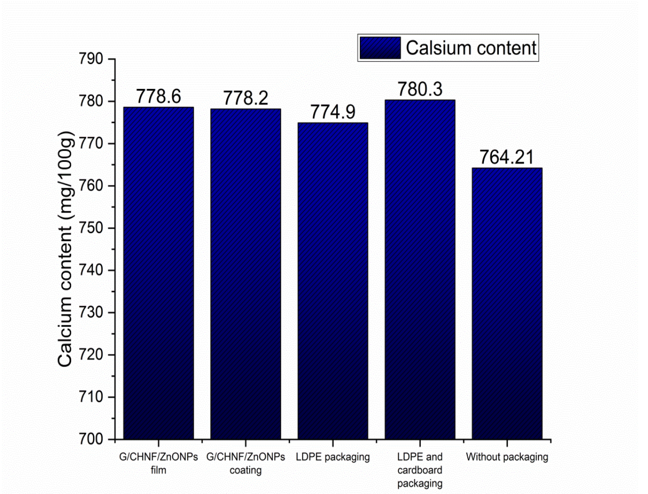

Fig. 4 Calcium content of cheddar cheese in various packaging after one-month

Based on the results, it is evident that the implementation of G/CHNF/ZnONPs film and coating effectively reduced the potential decrease in calcium levels in cheddar cheese by 1.83% and 1.78%, respectively, during storage in the absence of packaging. These results align with prior research that demonstrated a lower reduction in mineral content for grapes coated with a chitosan-based formula than those without coating during storage. The coating's ability to regulate enzymatic activity and reduce respiration contributed to this outcome [23].

E. Microbiological Activity

Microbiological analysis was performed on six cheese samples that were subjected to different treatments and stored for one month following the application of packaging. The study examined three kinds of bacteria that can cause food poisoning: *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*. Colonies of these bacteria were cultivated on *Mueller-Hinton agar* plates and incubated at 37°C for 24 hours. The size of the area where the bacteria were stopped was then measured using a tool that can measure small distances accurately.

Table V and Fig. 5 show how well the cheese could prevent the growth of three kinds of foodborne bacteria after being wrapped and kept for 30 days. The results showed that cheddar cheese with a combination of LDPE and cardboard packaging had the highest antibacterial activity compared to other cheddar cheese samples, followed by cheddar cheese with G/CHNF/ZnONPs film packaging, G/CHNF/ZnONPs coating, LDPE packaging, and without packaging. The relatively high antibacterial activity of cheddar cheese with G/CHNF/ZnONP-based packaging, both by casting and coating methods, is thought to be due to the presence of ZnONP and CHNF as one of the ingredients for the packaging which have antibacterial activity. There are two types of food wrapping that can stop bacteria from growing, depending on how they prevent food from being spoiled by microbes. They divided: (1) packaging that allows the migration of antimicrobial substances into food; and (2) Packaging that prevents growth on the food surface without leaching the antimicrobial substances into the food. Both systems need direct food contact, making them suitable for cheese, meat, fish, or poultry [32].

TABLE V
MICROBIOLOGICAL ACTIVITY AGAINST *S. AUREUS, P. AERUGINOSA*, AND *E. COLI* BACTERIA DURING ONE-MONTH STORAGE

No	Packaging Types	Inhibitory zone (nm)		
		S. aureus	*E. coli*	*P. aeruginosa*
1	G/CHNF/ZnONPs film	17.54	17.24	17.24
2	G/CHNF/ZnONPs coating	15.76	15.76	15.28
3	LDPE packaging	14.25	14.25	14.44
4	LDPE and cardboard packaging	22.79	22.79	22.59
5	Without packaging	0.00	0.00	0.00

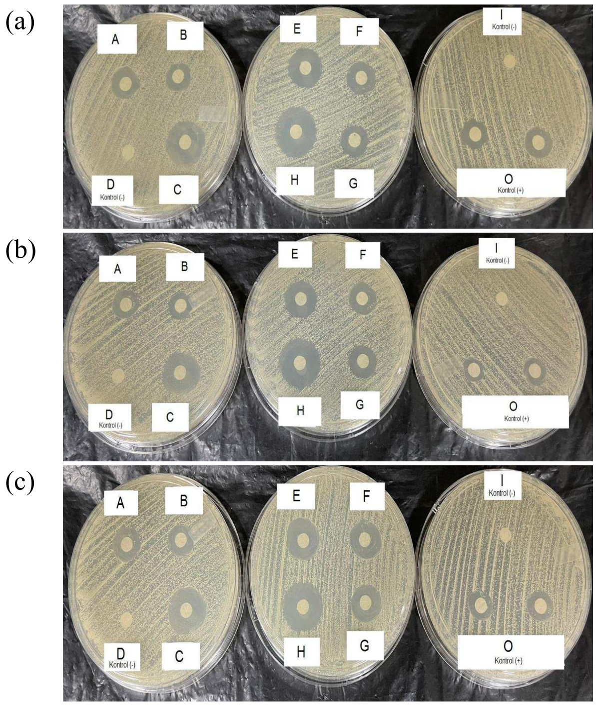

Fig. 5 Inhibition zone of (a) *Staphylococcus aureus*; (b) *Pseudomonas aeruginosa*; and (c) *Escherichia coli* bacteria from cheese samples E: film G/CHNF/ZnONPs; F: coating G/CHNF/ZnONPs; G: primary commercial packaging; H: primary and secondary commercial packaging; I: without packaging; O: without treatment (initial condition)

From the results obtained, it can also be seen that packaging can increase the antibacterial activity of cheddar cheese. It can be seen from the results of unpackaged cheese samples have the lowest inhibition zone compared to other cheese samples.

F. Shelf Life

One of the functions of food packaging is to increase the shelf life of the food product (see Fig. 6). Therefore, to determine the effectiveness of the G/CHNF/ZnONPs film as cheese packaging, a shelf-life test was carried out on packaged cheese. The testing process used the ASLT (Accelerated Shelf-Life Testing) method on cheese samples without G/CHNF/ZnONPs film packaging and cheese samples with G/CHNF/ZnONPs packaging. Tests were also carried out on cheese packaged with G/CHNF/ZnONPs coating, but also on cheese that had been packaged in LDPE packaging, which served as LDPE and cardboard packaging, and cheese without packaging. Cheese samples with a combination of LDPE and cardboard packaging acted as the positive control, while cheese without packaging acted as the negative control. In this study, the cheese packaging process was carried out, which was then followed by a storage process in the refrigerator for one month for cheese with G/CHNF/ZnONPs film packaging, G/CHNF/ZnONPs coating packaging, LDPE packaging, a combination of LDPE and cardboard packaging, and cheese without packaging.

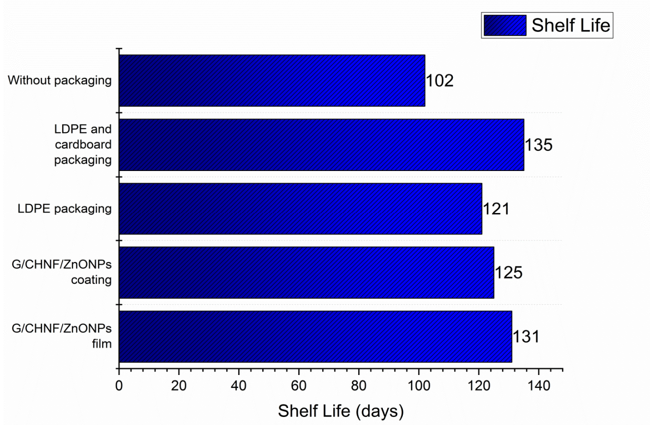

Fig. 6 The shelf life of cheddar cheese with various packaging

Shelf life is the period in which food meets the safety, nutritional, regulatory, and sensory criteria established by producers, governments, public and private institutions, and consumers under certain storage conditions [33]. The shelf life can be split into two parts: the primary shelf life and the secondary shelf life. The primary shelf life is the time when the food product is still in the packaging, while the secondary shelf life is the time after the packaging is opened [34]. During the shelf life, various chemical, physical, and biological reactions can happen in food products that can lower the safety and quality of the food so that the food product is deemed unacceptable. This phenomenon is called food spoilage because of microorganisms, enzymes, and physical and chemical degradation closely related to the previous intrinsic and extrinsic factors [35].

Cheese has various kinds based on how it is made, how it flows, how long it is fermented, how it feels, how much water it has, how much fat it has, and other factors. Cheese is classified into soft, semi-soft, semi-hard, and hard cheeses based on the amount of water [36], [37]. This study used hard cheese, namely cheddar cheese. These firm cheeses usually last 4-6 months in the fridge and 6-8 months in the freezer [38]. This type of cheese requires packaging that has low permeability [39].

The test results showed that cheese packaged with G/CHNF/ZnONPs film had a shelf life of 131 days and 125 days for G/CHNF/ZnONPs coating. It is longer than the negative control, cheese without packaging, for 102 days. Meanwhile, the shelf-life test results for LDPE packaging were 121 days, and for a combination of LDPE and cardboard packaging 135 days. These outcomes demonstrate that the G/CHNF/ZnONPs packaging can lengthen the shelf life of cheese. This is consistent with previous studies, which revealed that active packaging could lengthen the shelf life of cheese by reducing moisture and weight loss, stopping microbial growth, and preserving the sensory properties of cheese during storage.

IV. Conclusion

G/CHNF/ZnONPs nanocomposite films were prepared and applied to cheddar cheese for one month. The analysis of biological characteristics, including fat, protein, carbohydrates, and minerals contents, and microbiological activity showed that the nanocomposite film had a good ability as cheese packaging. In addition, the shelf-life analysis on cheddar cheese that has been stored for one-month shows the results for 131 days for film G/CHNF/ZnONPs and 125 days for coating G/CHNF/ZnONPs.

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