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Application of Natural Antioxidants from Cinnamon Extract in Extending the Oxidative Stability of Fish Crackers

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Abstract

The increasing consumer demand for clean-label food products has encouraged the exploration of natural antioxidants as alternatives to synthetic preservatives. Fish crackers are widely consumed snack products rich in unsaturated fatty acids, making them susceptible to lipid oxidation during storage. Cinnamon (Cinnamomum burmannii) is recognized as a rich source of natural antioxidant compounds, including cinnamaldehyde, eugenol, and polyphenolic substances with strong free radical scavenging activity. This study evaluated the effectiveness of cinnamon extract in improving the oxidative stability of fish crackers during storage. Four treatments were prepared by incorporating cinnamon extract at concentrations of 0%, 0.5%, 1.0%, and 1.5% (w/w) and stored at ambient temperature (27 ± 2°C) for 90 days. The results demonstrated that cinnamon extract significantly reduced lipid oxidation throughout storage. Fish crackers containing 1.0% cinnamon extract exhibited the lowest peroxide value and TBARS formation while maintaining favorable sensory characteristics. Antioxidant activity increased proportionally with cinnamon concentration, reaching 78.4% radical scavenging activity in samples containing 1.5% extract. The findings suggest that cinnamon extract can serve as an effective natural antioxidant for fish crackers and may provide a sustainable alternative to synthetic preservatives in snack food applications.

Keywords: Cinnamon extract, fish crackers, lipid oxidation, natural antioxidant, shelf life, oxidative stability

1. Introduction

Fish crackers are among the most popular traditional snack foods in Southeast Asia and are widely consumed due to their unique texture, flavor, and nutritional value. They are typically produced from fish meat, tapioca starch, seasonings, and other ingredients that undergo mixing, steaming, slicing, drying, and frying processes [1].

Despite their popularity, fish crackers are susceptible to oxidative deterioration during storage. Lipid oxidation is one of the primary causes of quality degradation in fish-based products. The oxidation process generates hydroperoxides and secondary oxidation products such as aldehydes, ketones, and alcohols that contribute to rancidity, unpleasant odors, off-flavors, discoloration, and nutrient losses [2].

Synthetic antioxidants such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) have traditionally been used to retard oxidation in food products. However, growing concerns regarding potential health risks associated with synthetic additives have stimulated interest in natural alternatives [3].

Cinnamon (Cinnamomum burmannii) is one of the most important spice commodities cultivated in Indonesia and has been widely recognized for its medicinal and antioxidant properties. Cinnamon bark contains numerous bioactive compounds, including cinnamaldehyde, eugenol, coumarin, catechins, and phenolic acids, which exhibit strong antioxidant activity through hydrogen donation, metal chelation, and free radical scavenging mechanisms [4, 5].

Fish lipids are particularly susceptible to oxidation because they contain high levels of polyunsaturated fatty acids (PUFAs). These fatty acids readily react with oxygen, producing hydroperoxides that further decompose into volatile compounds responsible for rancid flavors [7]. Therefore, the objective of this study was to investigate the effects of cinnamon extract incorporation on oxidative stability, physicochemical properties, microbial quality, and sensory characteristics of fish crackers during storage, and to determine the optimal concentration of cinnamon extract for maintaining product quality and extending shelf life.

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2. Literature Riview

2.1. Lipid Oxidation Mechanisms in Fish-Based Products

Lipid oxidation in fish products proceeds through a free radical chain mechanism involving initiation, propagation, and termination stages. The high proportion of polyunsaturated fatty acids in fish lipids accelerates this process, leading to the formation of primary oxidation products (hydroperoxides) and secondary products such as malondialdehyde [2, 7].

2.2. Cinnamon Bioactive Compounds and Antioxidant Mechanisms

Cinnamaldehyde and eugenol, the principal bioactive constituents of cinnamon, exhibit hydrogen-donating capacity that neutralizes free radicals and interrupts oxidative chain reactions. These compounds also chelate transition metals such as iron and copper, further reducing catalytic oxidation [4, 11].

2.3. Natural Antioxidants as Alternatives to Synthetic Preservatives

Increasing consumer preference for clean-label products has driven research into natural antioxidant sources capable of replacing synthetic additives such as BHA and BHT, while simultaneously offering antimicrobial and sensory-enhancing benefits [3, 8].

3. Methodology

3.1. Experimental Design

A Completely Randomized Design (CRD) was used with four treatments: C0 (0.0% cinnamon extract), C1 (0.5%), C2 (1.0%), and C3 (1.5%). Three replications were conducted for each treatment, with storage observations performed on Day 0, Day 30, Day 60, and Day 90 at room temperature (27 ± 2°C).

3.2. Fish Cracker Preparation

The primary ingredients used in fish cracker production included fish mince (threadfin bream), tapioca starch, garlic, salt, sugar, cinnamon extract, and water. The dough was mixed, steamed for 60 minutes, cooled, sliced, dried to approximately 10% moisture content, and fried before packaging.

3.3. Analytical Parameters

Physicochemical analyses included moisture content (AOAC method), water activity, color (L*, a*, b*), and texture hardness. Oxidative stability was assessed through peroxide value (PV), thiobarbituric acid reactive substances (TBARS), free fatty acids (FFA), and DPPH antioxidant activity [9]. Microbiological analysis included total plate count and yeast and mold count. Sensory evaluation was conducted by 30 semi-trained panelists assessing color, aroma, crispiness, flavor, and overall acceptability using a 9-point hedonic scale.

3.4. Statistical Analysis

All analyses were conducted in triplicate and expressed as mean ± standard deviation. Data were analyzed using one-way ANOVA followed by Duncan's Multiple Range Test (DMRT) at $p < 0.05$. Pearson correlation analysis was conducted to evaluate relationships between antioxidant activity and oxidative indicators.

4. Results and Discussion

4.1. Peroxide Value and TBARS

Peroxide values increased significantly ($p < 0.05$) during storage for all treatments. However, fish crackers containing cinnamon extract exhibited substantially lower peroxide values than the control, with the lowest PV observed in C3. A significant reduction in TBARS formation was also observed in cinnamon-treated samples; after 90 days, C3 exhibited a TBARS value approximately 52% lower than the control.

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Table 1. Peroxide value and TBARS of fish crackers after 90 days of storage.

Treatment	Peroxide Value (meq O2/kg)	TBARS (mg MDA/kg)
C0	13.74 ± 0.31	1.68 ± 0.05
C1	10.12 ± 0.28	1.29 ± 0.04
C2	7.35 ± 0.22	0.91 ± 0.03
C3	6.41 ± 0.20	0.80 ± 0.03

Values are means ± standard deviation of triplicate determinations.

4.2. Free Fatty Acids and Antioxidant Activity

The addition of cinnamon extract effectively slowed free fatty acid (FFA) accumulation, suggesting protection against hydrolytic degradation during storage. Antioxidant activity increased significantly with cinnamon extract concentration ($p < 0.05$), and Pearson correlation analysis revealed strong negative correlations between antioxidant activity and peroxide value ($r = –0.93$) as well as TBARS ($r = –0.91$).

Table 2. Free fatty acids and antioxidant activity of fish crackers.

Treatment	FFA Day 90 (% oleic acid)	DPPH Day 0 (%)	DPPH Day 90 (%)
C0	1.18 ± 0.05	12.6 ± 0.8	10.4 ± 0.7
C1	0.97 ± 0.04	45.7 ± 1.2	40.8 ± 1.1
C2	0.82 ± 0.03	63.4 ± 1.7	58.2 ± 1.6
C3	0.74 ± 0.03	78.4 ± 2.1	72.6 ± 1.9

Values are means ± standard deviation of triplicate determinations.

4.3. Color, Texture, and Microbiological Stability

Increasing cinnamon extract concentration resulted in lower lightness (L*) and increased redness (a*) and yellowness (b*) values. Texture remained relatively stable in cinnamon-treated samples, indicating improved structural preservation during storage. The antimicrobial properties of cinnamon also significantly inhibited microbial growth, with total plate counts in C3 reaching only 3.41 log CFU/g after 90 days compared to 4.82 log CFU/g in the control.

4.4. Sensory Evaluation

Fish crackers containing 1.0% cinnamon extract (C2) received the highest overall acceptability score. While C3 provided superior antioxidant protection, excessive cinnamon flavor slightly reduced consumer preference.

Table 3. Sensory scores of fish crackers on a 9-point hedonic scale.

Attribute	C0	C1	C2	C3
Color	7.2	7.8	8.3	8.1
Aroma	7.0	7.9	8.4	8.0
Crispiness	7.5	8.0	8.5	8.3
Flavor	7.3	8.1	8.6	7.7
Overall Acceptability	7.2	8.0	8.5	7.9

Values represent mean scores from 30 semi-trained panelists.

5. Conclusion

Cinnamon extract significantly improved the oxidative stability, microbial quality, and sensory characteristics of fish crackers during 90 days of storage. Increasing cinnamon concentration reduced peroxide value, TBARS formation, and free fatty acid accumulation while enhancing antioxidant activity. Fish crackers containing 1.0% cinnamon extract exhibited the most desirable balance between oxidative protection and sensory acceptability, supporting cinnamon extract as a promising natural preservation strategy capable of replacing synthetic antioxidants in fish-based snack products.

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