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Modification of Protein-Lipid Films from Kidney Bean Seeds (*Phaseolus Vulgaris L*) For Improved Functional and Antibacterial Properties in Food Packaging.

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ABSTRACT:
This study investigates the modification of protein-lipid films derived from kidney bean seeds *(Phaseolus vulgaris L)* using formaldehyde and ultraviolet (UV) light treatments to improve their functional properties for potential use in food packaging. The proximate, mineral, and functional properties of the films were analyzed, alongside their antibacterial efficacy against Escherichia coli (E. coli) and Staphylococcus aureus (S. aureus). The results showed that modified films demonstrated superior antibacterial activity, reduced water vapor and oxygen permeability, and improved mechanical properties compared to unmodified films. These findings suggest that modified kidney bean films could be a promising alternative for biodegradable food packaging materials, though furtherresearch is needed to optimize production processes and enhance their commercial viability.

KEYWORDS: Kidney Beans, Modification, Lipid Films, Food Packaging.

I. INTRODUCTION

Plastics are one of the most important materials employed in daily life. However, environmental pollution from their consumption has become a serious issue. To overcome this problem, biopolymers produced from natural resources are regarded as an attractive alternative since they are abundant, renewable, inexpensive, environmentally friendly and biodegradable [6].

Food packaging plays a critical role in preserving the quality, safety, and shelf life of food products. Edible films, made from natural biopolymers such as proteins, lipids, and polysaccharides, have emerged as a sustainable alternative to traditional plastic packaging. Among various protein sources, kidney bean (*Phaseolus vulgaris L*) seeds offer a rich composition of proteins, carbohydrates, and essential minerals, making them an ideal candidate for film development.

Protein-lipid films are formed as a result of endothermic polymerization of heat denatured proteins or lipoprotein monomers at the liquid surface promoted by surface dehydration [5].

However, for kidney bean-based films to be effective in food packaging, certain properties such as moisture resistance, mechanical strength, and antibacterial activity need to be enhanced. This study investigates the impact of formaldehyde and ultraviolet light modifications on kidney bean protein-lipid films, evaluating their physicochemical, functional, and antibacterial properties. The general objective of this work is to develop, characterize and modify protein-lipid films from Kidney bean (*Phaseolus vulgaris L*). The specific objectives of this work are to: determine the physical mechanical properties of pure and modified protein-lipid films from Kidney bean (*Phaseolus vulgaris L*); Determine the nutrient composition and functional properties of the pure and modified films; evaluate the minimum inhibitory concentration and minimum bactericidal concentration of the pure and modified protein-lipid films from Kidney bean (*Phaseolus vulgaris L*).

II. MATERIALS AND METHODS

Film Preparation

Kidney beans were used to extract protein-lipid film according to the flow chart below:

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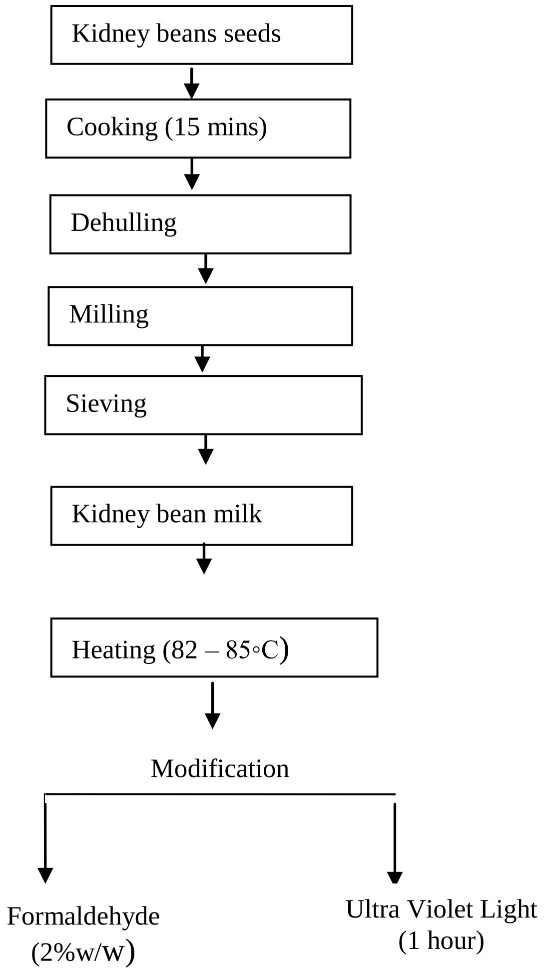

Figure 1: Flow chart of production of protein Lipid film developed from Kidney bean seed

Plate 1. Kidney bean film.

The films were categorized into three groups:
1. Unmodified Kidney Bean Film (KN) The pure, unmodified protein-lipid film.
2. Formaldehyde Modified Kidney Bean Film (KF) Protein-lipid film modified with formaldehyde.
3. Ultraviolet Light Modified Kidney Bean Film (KUV): Protein-lipid film modified by UV light exposure.

The films were dried under controlled conditions and then subjected to various tests.

Proximate Analysis

The proximate composition, including moisture content, protein, fat, fiber, ash, and carbohydrates, was determined using standard laboratory techniques [2].

Mineral Content Analysis

The mineral content (calcium, magnesium, zinc, iron, copper, potassium, sodium, and phosphorus) was analyzed using atomic absorption spectroscopy (AAS).

Antibacterial Activity

The minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of the films against E. coli and S. aureus were determined using the agar diffusion method.

Functional Properties

Key functional properties such as water absorption capacity (WAC), oil absorption capacity (OAC), and least gelation concentration (LGC) were evaluated to understand the behavior of the films under different conditions.

Physical Properties

The physical properties of the films, including film solubility, thickness, water vapor permeability (WVP), and oxygen permeability, were determined using established protocols.

Mechanical Properties

The mechanical properties, including compressive strength, strain, energy at break, and modulus, were measured using a universal testing machine.

III. RESULTS

Proximate composition of pure and modified film

Composition (%)	KF	KN	KUV
Moisture	26.65 ± 0.14^a	25.93 ± 0.01^b	22.72 ± 0.12^c
Protein	42.88 ± 1.15^a	35.34 ± 0.12^b	31.36 ± 0.58^c
Fat	25.68 ± 0.12^c	34.55 ± 0.81^b	38.43 ± 1.00^a
Ash	3.31 ± 0.18^c	3.57 ± 0.14^b	3.54 ± 0.12^c
Fibre	0.00^b	0.00^b	0.36 ± 0.01^a
Carbohydrate	1.47 ± 0.05^b	0.61 ± 0.06^c	3.19 ± 0.01^a

Table 1: Values are means of triplicates samples. Values

Proximate Composition

The analysis revealed significant differences in the proximate composition between the unmodified and

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modified films. Kidney beans have been reported to be a good source of protein[2]. Modified films showed a reduction in moisture content, with the UV-modified films exhibiting the lowest moisture, protein, and fat content. The formaldehyde-modified films exhibited higher protein content compared to both the unmodified and UV-modified samples. Losses in the nutritive values in crude fiber may be due to total dehulling/debranning of the kidney bean seeds during the production of protein-lipid film [1].

Mineral Content

The mineral content of the modified films was significantly different from the pure sample. The formaldehyde-modified films had the highest calcium content, followed by the UV-modified films. Magnesium, zinc, and copper contents were higher in the UV-modified films, while potassium and sodium levels were increased in both modified films compared to the unmodified sample.

Antibacterial Activity

The modified films exhibited enhanced antibacterial activity compared to the unmodified film. S. aureus was more susceptible to the films, with larger inhibition zones compared to E. coli. The modified films, particularly at higher concentrations (800-1000 mg/ml), showed significant antibacterial efficacy, with no growth of E. coli at 1000 mg/ml concentrations.

Functional Properties

Functional Properties of pure and modified protein Lipid film from Kidney bean

Property	KF	KN	KUV
OAC (gml)	0.55±0.03^{b}	0.70±0.00^{a}	0.15±0.03^{c}
WAC (gml)	0.35±0.03^{a}	0.20±0.00^{b}	0.10±0.00^{c}
Least Gel (%)	0.80±0.00^{c}	1.00±0.00^{b}	1.10±0.00^{a}

Table 2: Values are means of triplicates samples. Values followed by different alphabets along the same row are significantly different at ($p \leq 0.05$)

KEY : KN: Unmodified kidney bean film; KF: Formaldehyde modified kidney bean film; KUV: Ultraviolet light kidney bean film.

The water absorption capacity (WAC) was significantly higher in the unmodified films, while the oil absorption capacity (OAC) was highest in the unmodified sample. The least gelation concentration (LGC) of the UV-modified film was the highest, indicating better gelling properties.

Physical Properties

Physicochemical properties of protein Lipid films developed from Kidney bean

	Film Thickness (mm)	Film Formation Rate (g/10min)	Film Yield (g/100ml)	Solubility in Water (%)	Water Vapour Permeability (g·mm/(m2·Kpa)	OxygenPermeability(cc·µm/(m.Kpa)	Colour
SN	1.38±0.13^{a}	3.68±0.21^{a}	10.02±0.43^{a}	0.68±0.05^{a}	11.80±0.05^{a}	2.13± 0.02^{b}	11.10±0.00^{a}
KN	0.88±0.30^{c}	2.87±0.14^{d}	5.06±0.24^{d}	8.70±0.09^{a}	9.45±0.076^{c}	3.69±0.05^{a}	9.00±0.00^{b}
KF	1.40±0.30^{a}	3.63±0.07^{b}	6.50±0.35^{b}	5.87±0.06^{c}	10.12±0.02^{b}	1.53±0.17^{C}	11.00±0.00^{a}
KUV	1.10±0.30^{b}	3.03±0.15^{c}	5.68±0.11^{c}	6.70±0.14^{b}	7.76±0.15^{d}	1.16±0.11^{d}	8.00±0.00^{c}

Table 3. Values are means of triplicates samples. Values followed by different alphabets along the same row are significantly different at ($p \leq 0.05$)

KEY : KN: Unmodified kidney bean film; KF: Formaldehyde modified kidney bean film; KUV: Ultraviolet light kidney bean film

The film solubility was significantly lower in the modified films, indicating better water resistance. The water vapor permeability (WVP) and oxygen permeability were both reduced in the modified films, with the UV-modified films showing the lowest permeability values, suggesting an improved barrier against moisture and oxygen.

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Mechanical Properties

Mechanical properties of pure and modified protein lipid film.

	Compressive extension at Break (mm)	Compressive strain at Break (%)	Compressive load at Break (N)	Compressive stress at Break (MPa)	Energy at Break (J)	Modulus (Automatic) (MPa)
SN	24.91641	143.19774	22.12759	0.02481	0.18372	0.03828
KN	26.34984	263.49845	0.27745	0.00039	-0.00452	0.29280
KF	32.39985	323.99845	1.39586	0.00197	0.00139	0.148095
KUV	36.91703	369.17031	3.02603	0.00428	0.02465	0.00339

Table 4. Values are means of triplicates samples. Values followed by different alphabets along the same row are significantly different at ($p \leq 0.05$)KEY : KN: Unmodified kidney bean film; KF: Formaldehyde modified kidney bean film; KUV: Ultraviolet light kidney bean film.

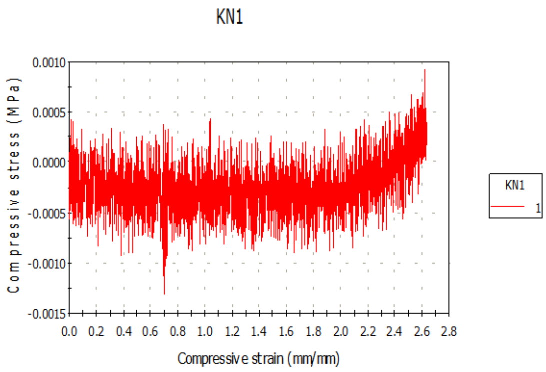

Figure 2. Compressive test of pure(unmodified) film sample

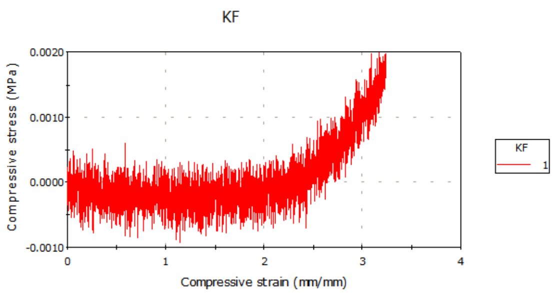

Figure 1. Compression Test of formaldehyde modified sample

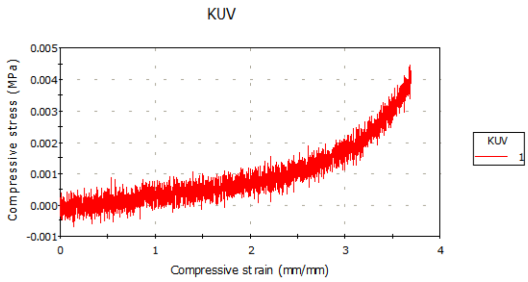

Figure 3. Compression Test forUV modified sample

The mechanical properties, including compressive strength, strain at break, energy at break, and modulus, showed significant improvements in the modified films. The UV-modified films exhibited the best mechanical properties, followed by formaldehyde-modified films, while the unmodified films had the lowest values. Brandenburg[4] also found that alkaline treatment on Soy protein isolate improved the film's appearance and elongation at breaking points.

IV. DISCUSSION

The modification of kidney bean protein-lipid films using formaldehyde and ultraviolet light significantly enhanced their functional, mechanical, and antibacterial properties. The increase in calcium and magnesium content in the modified films may contribute to their improved structural integrity and moisture resistance. The antibacterial activity against E. coli and S. aureus suggests that the modified films could help extend the shelf life of food products by preventing bacterial contamination.

The improvement in film solubility, water vapor permeability, and oxygen permeability highlights the potential of modified films for use in food packaging applications. The reduced solubility and permeability in the modified films suggest that they may offer better protection against environmental factors, including moisture and oxygen, which are key determinants of food spoilage.

Moreover, the enhanced mechanical properties of the modified films make them more suitable for practical applications, as they offer better durability and resistance to breakage. These improvements demonstrate the effectiveness of the modification methods in enhancing the properties of kidney bean protein-lipid films.

V. CONCLUSION

In conclusion, the study demonstrates that modification of kidney bean protein-lipid films using formaldehyde and ultraviolet light treatments enhances their functional properties, including antibacterial activity, mechanical strength, and barrier properties. These findings suggest that modified kidney bean films could be a promising alternative for edible food packaging, offering improved shelf life and food safety. However, further research is necessary to optimize film production processes and explore the potential for large-scale commercial use.

VI. RECOMMENDATIONS

1. Use in Food Packaging: Modified kidney bean films should be explored further for food packaging applications, particularly in areas where antibacterial properties are needed to extend shelf life.
2. Optimization of Production Methods: Modern equipment should be introduced to standardize the production process of edible films, improving the rate of film formation and ensuring consistent quality.
3. Additives for Enhanced Properties: Future studies could focus on incorporating additional additives to further enhance the mechanical and functional properties of the films, including their flexibility, strength, and barrier performance.
4. Large-Scale Production: Further studies should explore the feasibility of large-scale production of these modified films for commercial applications, including their cost-effectiveness and scalability.

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