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Research Article

Effect of edible gum coating and biodegradable film packaging with ginger extract on sensory attributes of chicken nuggets

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Abstract

In the present study, efforts were made to develop the biodegradable film and evaluate sensory quality of chicken nuggets packaged in developed film. Biodegradable film was prepared by using corn starch and storage study was designed by packaging chicken nuggets into four different packaging films viz., C (control) - Low Density Polyethylene (LDPE), T_1- developed film from corn starch, T_2- developed film from corn starch with coating of edible gum and T_3- coating of edible gum on developed film from corn starch with incorporation of ginger extract. In most of the sensory parameters, T_1 and T_2 had significantly ($p<0.01$) lower scores than the control; however, T_3 had comparable scores to the control. Based on the values of sensory quality of chicken nuggets, the edible gum coated corn starch-based film incorporated with ginger extract was found superior and can be an excellent alternative to LDPE film.

Keywords: Biodegradable film, Chicken nuggets, Ginger extract, Sensory quality

Highlights

- Development of corn starch-based biodegradable film along with gum is a futuristic approach.
- Corn starch based biodegradable film has its own limitations over plastics.
- Corn starch is most abundant, cheaper and can be used as biodegradable packaging material.

INTRODUCTION

Conventional packaging materials produced by petroleum and their byproducts have been in use for several years by the food packaging industry (Perera *et al*., 2023). But, petroleum-based conventional packaging has serious global environmental problems that can indirectly threaten humans' and animals' health. The most effective solution to this problem is their substitution with biodegradable packaging materials (Rai *et al*., 2021). Therefore, the use of biopolymers as packaging materials instead of plastic is an upcoming trend globally due to their key benefits of biodegradability, eco-friendly nature, nontoxicity and biocompatibility (Perera *et al*., 2023).

Biodegradable film or packaging can be used either as edible form or inedible form. Biodegradable film is made from eco-friendly material, which makes it easier to recycle. Biopolymers commonly used for food packaging are polysaccharides, proteins, and aliphatic polyesters, which have barrier properties that control the exchange of gases, moisture and aroma from the external environment (Chaudhary *et al*., 2020).

A food packaging material should maintain several physicochemical, sensory and microbial properties including avoiding spoilage, oxidation, and preserve color, texture, nutritional value, and other quality for the acceptance and safety of the product as well as to improve the product's shelf life (Kumar *et al*., 2022). Though biodegradable packaging has many advantages over plastics, they have their own limitations, such as their weak mechanical strength and high sensitivity to moisture (Perera *et al*., 2023).

Biodegradable polymers currently used for food packaging materials are starch, cellulose, alginates, carrageen, pectin, chitosin, agar, gums and polylactic acid (PLA) that can be commonly extracted from plants,

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marine and animal sources. Among biopolymers, starch is mostly used due to its biodegradability, relative abundance, low cost as well as its excellent film forming capabilities (Sudheesh *et al*., 2020). Starch is found commonly in plants such as corn, potatoes and wheat. Corn starch is around 80% of the world's creation of starch extracted from corn pieces through wet processing (Marichelvam *et al*., 2019). Corn starch polymer has become very popular as a replacement for traditional plastics due to its unique functional properties, lack of odor, low cost and availability (Xu *et al*., 2012). Natural gums have increased interest recently in the preparation of polymer due to their rheological qualities and structural variety (Salehi, 2020).

Nowadays, advanced packaging is utilized to improve shelf life, such as active packaging, where subsidiary constituents have been deliberately included in or on either the packaging material or the package headspace to enhance the performance of the package system (Suppakul *et al*., 2003). Antimicrobial packaging includes the addition of antimicrobial-containing sachets/pads into food packages or direct incorporation of antimicrobials into food packaging materials or the use of packaging materials that are inherently antimicrobial. Ginger (*Zingiber officinale*) is associated with a number of health benefits in a variety of food products due to its various biological properties, such as antimicrobial, antioxidant and anti-fungal activities (Mao *et al*., 2019).

The objective of this study was to explore starch-based material as an alternative to plastic for packaging of meat products. Here, starch-based packaging film was developed with gum coating and ginger extract addition, and the sensory quality of the packaged chicken nuggets was evaluated during storage at refrigeration temperature (4±1°C).

MATERIALS AND METHODS

Source of raw material

The chicken meat was procured from the local market and deboned manually. All the chemicals used in the experiment were of analytical grade and obtained from standard firms (Qualigens, Hi Media, Polypharm, SRL etc.). Corn starch, glycerine, acetic acid, edible gum, refined wheat flour (maida), oil, sugar, salt, spices and other ingredients of food grade were procured from the local market. Condiments (onion and garlic) were purchased from local markets. Food grade low-density polyethylene (LDPE) films (250 gauges) were also procured from the local market for packaging of the product.

Preparation of ginger extract: Ginger extract was prepared by using the procedure followed by Chen *et al*. (2020). Ginger rhizomes were cut into pieces, washed, and oven-dried at 50°C for 10 hrs. The dried roots were ground into powder in a mixer. 100 g of powdered ginger was added to 1 L of distilled water and subjected to shaking at high speed. The obtained mixture was then filtered (sterile Whatman No.1 filter paper) and placed in desiccators for final concentration. The obtained extract was stored in a refrigerator in light and air-insulated glass until use.

Experiment design

According to packaging material and their modifications, four groups were prepared for the storage study of chicken nuggets, which included one control of LDPE and three treatments viz., T_1, T_2 and T_3. T_1 was composed of corn starch-based biodegradable film, T_2 of corn starch with the coating of edible gum, and T_3 was a coating of edible gum on the biodegradable film of corn starch with the incorporation of ginger extract. Packaged products were stored at refrigeration temperature and samples were analyzed from day 0 at regular intervals of 4 days for a period of 16 days.

Development of biodegradable film Preparation of packaging film T_1: Biodegradable film of corn starch was prepared as per the modified method of Karthikeyan *et al*. (2016). 5 g (W/V) of corn starch was mixed thoroughly in 100 mL of distilled water on a hot plate with temperature around 150°C. Glycerine 1 % (V/V) as a plasticizer and 1 mL of acetic acid (1%) were added to the mixture. As the mixture approached a pasty texture, it was transferred to the spreading area. The mixture was spread as per the thickness required and placed for drying in a hot air oven at 35-40°C for 20-24 h, and on the next day the dried film was peeled off.

Preparation of packaging film T_2: Edible gum from the babool plant (*Vachellia nilotica*) was dissolved in equal proportion of distilled water and spread over the dried and peeled corn film sheet obtained as in the T_1 variant on a single side and placed in a hot air oven for 1-2 h at 45°C, thereafter they were stored for further packaging of chicken nuggets.

Preparation of packaging film T_3: The process of preparation of packaging film T_3 was similar to the process of preparation of T_2, except 10% of prepared ginger extract was added just before casting and mixed properly.

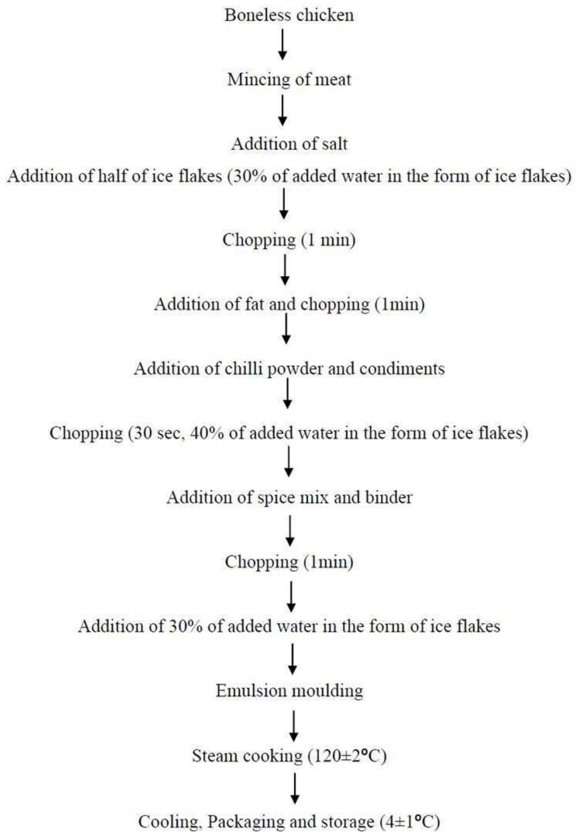

Fig. 1. Flow diagram chart for the preparation of chicken nuggets

Preparation of chicken nuggets

Chicken nuggets were prepared using the method given by Kumar and Tanwar (2011), as shown in Fig. 1. After cooling, the nuggets were packaged using the designed packaging materials for storage study.

Sensory evaluation

The chicken nuggets packaged in different packaging materials were evaluated by an experienced panel of judges consisting of seven members for the sensory attributes of color and appearance, texture, flavor, juiciness etc. using 8-point descriptive scale (Keeton, 1983), where 8 = excellent and 1 = extremely poor. The test samples were presented to the panelists after assigning the suitable codes. Water was served to rinse the mouth between the samples for the sensory evaluation.

Statistical analysis

Each experiment was analyzed by statistical method of two way ANOVA and Mean ± S.E. as per the procedure of Snedecor and Cochran (2007) using IBM SPSS Statistics software (Version 22.0 for Windows, Chicago, USA). The data were subjected to analysis of variance, least significant difference, and Duncan's multiple range tests to compare the means to find the difference between groups and storage periods. The smallest difference (D5%) for two means was reported as significantly different ($p<0.05$).

RESULTS

Mean ± SE scores for the sensory evaluation of chicken nuggets packaged in corn starch based biodegradable film stored at refrigeration temperature (4±1°C) are presented in Table 1.

Table 1. Sensory characteristics of chicken nuggets packaged in corn starch based biodegradable film stored at refrigeration temperature (4±1°C)

Treatment	Storage days				
	0	4	8	12	16
	General appearance/Color				
C	$7.42^{A}\pm0.05$	$7.29^{AB}\pm0.04$	$7.17^{aB}\pm0.05$	$6.92^{aC}\pm0.05$	$6.71^{aD}\pm0.04$
T_1	$7.43^{A}\pm0.05$	$7.17^{B}\pm0.05$	$6.92^{bC}\pm0.08$	$6.50^{bD}\pm0.06$	$6.42^{bD}\pm0.05$
T_2	$7.42^{A}\pm0.05$	$7.21^{B}\pm0.08$	$7.08^{aC}\pm0.05$	$6.71^{abC}\pm0.1$	$6.63^{aC}\pm0.06$
T_3	$7.42^{A}\pm0.05$	$7.25^{AB}\pm0.06$	$7.13^{aB}\pm0.06$	$6.75^{aC}\pm0.06$	$6.67^{aC}\pm0.05$
	Flavor				
C	$7.29^{A}\pm0.08$	$7.21^{A}\pm0.12$	$7.08^{aAB}\pm0.11$	$6.88^{aBC}\pm0.09$	$6.67^{aC}\pm0.08$
T_1	$7.30^{A}\pm0.08$	$7.08^{A}\pm0.12$	$6.71^{bB}\pm0.10$	$6.42^{bC}\pm0.05$	$6.17^{cD}\pm0.05$
T_2	$7.30^{A}\pm0.08$	$7.13^{AB}\pm0.14$	$6.88^{abBC}\pm0.11$	$6.63^{abCD}\pm0.11$	$6.46^{abD}\pm0.08$
T_3	$7.29^{A}\pm0.08$	$7.17^{A}\pm0.12$	$7.00^{abAB}\pm0.13$	$6.75^{aB}\pm0.09$	$6.42^{bC}\pm0.08$
	Texture				
C	$7.13^{A}\pm0.06$	$7.04^{AB}\pm0.08$	$6.92^{aB}\pm0.05$	$6.71^{aC}\pm0.04$	$6.50^{aD}\pm0.06$
T_1	$7.13^{A}\pm0.06$	$6.88^{B}\pm0.06$	$6.58^{bC}\pm0.05$	$6.33^{bD}\pm0.05$	$6.08^{cE}\pm0.05$
T_2	$7.14^{A}\pm0.06$	$7.00^{A}\pm0.06$	$6.75^{abB}\pm0.06$	$6.50^{abC}\pm0.11$	$6.25^{bcD}\pm0.11$
T_3	$7.13^{A}\pm0.06$	$6.96^{AB}\pm0.08$	$6.79^{abB}\pm0.1$	$6.58^{aC}\pm0.05$	$6.33^{abD}\pm0.05$

Cont. Table 1.

Table 1., Cont. ...

Treatment	Storage days				
	0	4	8	12	16
Juiciness					
C	$7.08^{A}\pm0.05$	$7.00^{AB}\pm0.06$	$6.88^{aB}\pm0.06$	$6.67^{aC}\pm0.05$	$6.42^{aD}\pm0.05$
T_1	$7.08^{A}\pm0.05$	$6.83^{B}\pm0.08$	$6.50^{cC}\pm0.06$	$6.17^{cD}\pm0.05$	$5.92^{bE}\pm0.05$
T_2	$7.08^{A}\pm0.05$	$6.92^{B}\pm0.05$	$6.63^{bcC}\pm0.06$	$6.42^{bD}\pm0.05$	$6.08^{bE}\pm0.05$
T_3	$7.08^{A}\pm0.05$	$6.96^{AB}\pm0.08$	$6.75^{abBC}\pm0.09$	$6.54^{abC}\pm0.08$	$6.29^{aD}\pm0.08$
Overall acceptability					
C	$7.17^{A}\pm0.05$	$7.04^{AB}\pm0.04$	$6.92^{aB}\pm0.05$	$6.67^{aC}\pm0.05$	$6.46^{aD}\pm0.04$
T_1	$7.17^{A}\pm0.05$	$6.83^{B}\pm0.08$	$6.54^{bC}\pm0.08$	$6.25^{cD}\pm0.06$	$6.04^{cE}\pm0.04$
T_2	$7.18^{A}\pm0.05$	$6.92^{B}\pm0.08$	$6.79^{aB}\pm0.08$	$6.46^{bC}\pm0.08$	$6.25^{bC}\pm0.09$
T_3	$7.17^{A}\pm0.05$	$6.96^{B}\pm0.08$	$6.88^{aB}\pm0.06$	$6.50^{abC}\pm0.06$	$6.42^{abC}\pm0.05$

Means (Mean ± SE, n = 21) with different superscripts in lower case in a column and upper case in a row differ significantly ($p\leq0.05$). C = Control, T_1 = Film prepared from corn Starch, T_2 = Film prepared from corn starch + coating of edible gum and T_3 = Film prepared from corn starch incorporated with ginger extract + coating of edible gum

Color/general appearance: The color scores followed a declining trend from day 0 to day 16 and were found in order of $C>T_3>T_2>T_1$ among different groups. T_1 had significantly ($p<0.05$) lower and C had significantly ($p<0.05$) higher color scores during entire storage. On storage day 16, a significantly ($p<0.05$) lower score of color was viewed in T_1; however, scores of C were comparable to T_2 and T_3.

Flavor: Irrespective of the type of packaging material, the flavor scores significantly ($p<0.05$) decreased with an increase in the storage period. On storage days 8, 12 and 16, a significantly ($p<0.05$) higher flavor score was seen in C, while a significantly ($p<0.05$) lower score was seen in T_1. Significantly ($p< 0.05$) different flavor scores were observed on storage day 16, which was in the sequence of $C>T_1>T_3$; however, flavor scores of T_2 were comparable to C and T_3.

Texture: The scores of textures generally declined with advancement in storage days. During storage days, a statistical ($p<0.05$) decrease in texture scores was observed in C and T_2 from day 8 to day 16, in T_3 from day 12 to day 16, and in T_1 from day 0 to day 16. In between groups, on days 8, 12 and 16, a significantly ($p< 0.05$) higher texture score was observed in C, while a significantly ($p<0.05$) lower score was observed in T_1. The texture score of T_3 was non-significantly ($p>0.05$) higher than T_2 during the whole study.

Juiciness: In this study, the mean scores of juiciness showed a decreasing trend with the progress of the storage period. A significant ($p<0.05$) decrease in juiciness scores was noticed in T_1 and T_2 from day 0 to day 16, in C from day 8 to day 16 and in T_3 from day 12 to day 16. On storage days 8, 12 and 16, a significantly ($p<0.05$) higher score of juiciness was observed in C, while a significantly ($p<0.05$) lower score was observed in T_1. On the final day of storage, a significantly ($p<0.05$) higher score of juiciness was seen in both C and T_3 as compared to T_1.

Overall acceptability: On the final day of storage, the mean scores of overall acceptability of chicken nuggets packaged in different films stored at refrigeration temperatures (4±1°C) were 6.46±0.04, 6.04±0.04, 6.25±0.09 and 6.42±0.05 for C, T_1, T_2 and T_3 respectively. Overall acceptability scores of chicken nuggets decreased with the advancement of the storage period. The overall acceptability scores of all four groups were within acceptable limits. A significant ($p< 0.05$) decrease in scores of overall acceptability was noticed in T_1 from day 0 to day 16 and in C from day 8 to day 16.

In between groups, on days 8, 12 and 16, a significantly ($p<0.05$) higher score of overall acceptability was observed in C, whereas a significantly ($p<0.05$) lower score was observed in T_1. On day 16, statistically ($p<0.05$), different scores of overall acceptability were observed in the order of $C>T_2>T_1$; however, score of C was comparable to T_3.

DISCUSSION

The sensory evaluation showed that all sensory criteria including color/appearance, flavor, texture, juiciness and overall acceptability, the packaged products declined during storage at refrigeration.

Starch based biodegradable films are known to be an effective barrier to gas transport (O_2, CO_2) and a poor barrier to water vapor (Donhowe and Fennema, 1994). The reason for low color score in T_1 might be due to progressive moisture loss, which results desiccation and concentration of pigments on surface of meat, forming crust layer and leading to poor visual scores. A high score of color was observed in C due to the good barrier and mechanical properties of LDPE packaging material. T_2 and T_3 had comparable color scores with C, probably due to gum coating, which improved the barrier property in T_2, while additionally, ginger extract showed antibacterial properties in T_3. It has been suggested that promising gas barriers in the form of film, antioxidant, and antimicrobial effects of the film could decrease the oxidative effects that preserve the natural color of meat (Gharibzahedi *et al.*, 2017). Similar result of decrease in color score was also observed by Mahajan *et al.* (2019) in functional meat nuggets wrapped in biodegradable films stored at refrigeration temperature (4±1°C); however, moisture losses were prevented due to water barrier properties of Zein based films.

The mean scores for flavor of all the packaged products decreased significantly ($p<0.05$) as the storage period advanced. This reduction in flavor scores of meat products during refrigerated storage could be attributed to the increased lipid oxidation, liberation of fatty acids, increased microbial load and loss of volatile flavor components from spices and condiments (Chandralekha *et al.*, 2012; Raja *et al.*, 2014). Similar decreasing pattern in flavor scores of chicken nuggets during refrigerated storage was also reported by Singh *et al.* (2022) in LDPE film, Mahajan *et al.* (2019) in biodegradable film and Kristam *et al.* (2016) in edible coatings.

Comparatively higher flavor scores in C than treatments might be due to their good mechanical and barrier property. Significantly ($p<0.05$) lower flavor scores in T_1 might be due to their relatively poor barrier property and interaction of chicken nuggets with biodegradable packaging film. T_2 and T_3 had significantly ($p<0.05$) higher values than T_1 due to the incorporation of gum that improved the barrier property; however, T_3 had slightly lower flavor scores than T_2, indicating the interaction of ginger extract with meat products, packaging material or incorporated gum. A result of compatibility of ginger flavor with meat was obtained by Sayadi *et al.* (2021) in a study on film of zein coating impregnated with ginger extract in packaging of bovine meat.

Significantly ($p<0.05$) lower texture score in T_1 can be related to its poor barrier property leading to evaporation of moisture and this low moisture content and higher microbial load reducing the texture scores. Jay (1996) also reported loss of moisture leading to hardening of texture, breakdown of fat and degradation of muscle fibre proteins by bacterial action that could decline texture scores of products. Comparatively higher texture scores of T_2 and T_3 than T_1 might be an account of improved barrier properties by gum incorporation in T_2 and T_3 and the antimicrobial activity of the added ginger extract in T_3.

The juiciness scores showed a decreasing fashion with progress of storage period that might be due to relative gradual loss of moisture from the packaged chicken nuggets stored at refrigeration. This decreasing trend of juiciness was in agreement with the study of Sharma *et al.* (2021) in meat products packaged in bioactive edible film and Kristam *et al.* (2016) in chicken nuggets packaged in edible coatings. Significantly ($p<0.05$) higher juiciness scores were observed in C and T_3 in comparison to T_1 and T_2. In C, LDPE film acts as a good barrier; however, in T_3, gum incorporation enhances the barrier of biodegradable film, and the antimicrobial activity of ginger extract results in more moisture retention in respective products.

The decreasing trend of overall acceptability during refrigerated storage reflects decline in scores of color/appearance, flavor, texture and juiciness of the product with progress of storage days. Similar decreasing results of overall acceptability was observed by Sharma *et al.* (2021) and Sayadi *et al.* (2021) during refrigerated storage of meat products packaged in edible/biodegradable film. Significant ($p<0.05$) reduction of overall acceptability scores observed in T_1 was probably due to their significantly ($p<0.05$) lower score of color/appearance, flavor, texture and juiciness. The overall acceptability scores of T_3 were higher than T_1 and T_2, as well as comparable to C, probably due to their superior scores of color, flavor, texture and juiciness.

Thus, the incorporation of edible gum in biodegradable film led to the improvement of mechanical and barrier properties, and ginger extract improved the microbial quality. The starch based biodegradable film incorporated with edible gum and ginger extract was promising and had a good potential to enhance the safety and also shelf-life of chicken nuggets stored under refrigeration. Hence, corn starch based biodegradable film incorporated with edible gum and ginger extract can be an effective to LDPE film.

Conflict of interest: Authors declare that they do not have any conflict of interest in the study.

Author's contributions: BSR: Has carried out all the experiments related to this manuscript; SKM, PKS: Designed and supervised the study; ST, NS, BD, SK, AS: Contributed to writing and statistical analysis of the work done.

Data availability statement: All the data supporting the research findings have been presented in this paper. The corresponding author is willing to provide the raw data upon reasonable request.

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