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Migration and storage study of food products packed in biodegradable films (LDPE and Modified Corn Starch)

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Abstract

This study focuses on the migration and storage properties of biodegradable films made from a blend of Low-Density Poly Ethylene (LDPE) and modified corn starch with food products. The overall migration (OM) from the biodegradable film in contact with food products such as potato chips and biscuits were investigated for six months using simulant 'D' as per IS 9845:1988. During the migration study, the highest OM was 3.94 mg/dm^2 for potato chips and 3.47 mg/dm^2 for biscuits, respectively within the permissible limit as per standards. The moisture content of the biodegradable films (T_1 and T_2) containing potato chips remained consistent with the product standard specification for up to four months. When biodegradable films containing biscuits T_1 and T_2 were compared to T_0 up to four months, they showed 3.61% and 4.02% moisture content, respectively, indicating suitability as a packaging material. Results showed that the peroxide value (PV) of potato chips packed in films of all treatments increased from 1.91 to 6.87 meq kg^{-1} from 1 to 3 months which indicates the suitability of biodegradable film as a food packaging material. The findings revealed that the OM rate was affected by the type of food packed, duration of contact, and the type of packaging material, well within specifications of the Bureau of Indian Standards. Hence, this biodegradable film can be used for packing food products (Biscuits, Chips) safely.

Keywords biodegradable film, food package, food safety, modified corn starch

Introduction

Consumers are focusing on nutritional and sensory characteristics of food products, and developing a more comprehensive understanding of the concept of food product quality and safety [1]. Safety is equally important in the food industry. Plastics are widely used for food packaging. Additives such as plasticizers, thermal stabilizers, lubricants, etc. abound in most plastics. Adipic acid, toluene, butanone-2, ethyl acetate, and hexane are some of the solvents that migrate, and pigments like molybdate orange tend to migrate into food [2]. Migration, defined as the mass transference of constituents from the packaging material to the foodstuff, is one of the most important processes that occur as a result of food packaging. This diffusion process has a considerable consequence on the properties of the packaging material [2]. Due to the extremely composite chemical and physical structure of foods, migration tests are usually made using food simulants [3]. All packaging materials of plastic origin must clear the prescribed OM limit of 60mg/kg or 10mg/dm^2 once tested according to IS 9845 with no visible color migration, according to the Food Safety and Standards (Packaging) regulations, 2018. Whereas, according to Article 2 of Directive 89/109/EEC, materials and articles must not transfer their constituents to foodstuffs in quantities that endanger human health or cause an unacceptable change in the composition of the foodstuff in their finished state. There have been several studies on the OM levels of LDPE. For example, Jagadish et al., [4] investigated the food compatibility of LDPE-vanillin films to check the OM as per IS: 9845:1988. The simulating solvent was chosen based on the type of foods for the study.

During the storage, oxidation occurs in potato chips and biscuits, indicating that lipid oxidation is the primary cause of spoilage. Due to moisture uptake and the high-fat content, the most quality-related degradation that occurs during storage are loss of crispness and rancidity [5].

This study aimed to determine reliable OM levels into the food simulant allowed by legislation IS 9845: 1998 by using simulant 'D' (n-heptane). The main objective was to estimate migration and product quality evaluation of biodegradable films used in food contact materials during storage. The findings are discussed in terms of how different factors affect the rate of migration.

Methodology

Materials

Biodegradable films

For overall migration testing, a biodegradable film composed of LDPE and modified corn starch was used. The virgin LDPE film was considered blank. The biodegradable films thickness ranges from 80 to 155 μ depending on the percentage of modified corn starch content.

Sampling

The products chosen for testing were chips (potato) and biscuits. Both the products were bought from the university cooperative store, weighed, and sealed with a heat impulse sealing machine (Model No. 300, Make: Sevana, Kochi, India), and kept at room temperature for six-months migration and storage study. Five samples of each product were prepared and analyzed as described below. All the treatments were done in triplicate. The research was conducted at the Department of Food Process Engineering, SHUATS, Prayagraj, India.

Chemicals and standard solutions

All the reagents were of analytical quality. Rankem (Thane, India) supplied n-heptane, sodium thiosulphate was purchased from Loba Chemie Pvt Ltd, Mumbai.

Methods

Preparation of specimen

The film samples were rolled in concentric rings in the form of a coil with a surface area of 100 cm^2 on both sides. To completely immerse the sample, 100 ml of simulant was taken.

Procedure

At the test temperature, the cylindrical jar with a capacity of 500 ml was filled with 100 ml of preheated simulant. The test specimen (5cm×10cm×2 sides) was completely immersed in the simulant and shielded by a glass plate. The jar with the sample was immersed in the simulant for 30 min at 38°C. The samples were removed with the help of a glass rod at the end of the test period. The samples were washed with a small amount of fresh simulant and combined with the extractants. By evaporating the extracted simulant by distillation, the volume was reduced to 10-15 ml. The concentrate was then transferred to a clean tared stainless-steel dish and washed three times with a small amount of fresh simulant before evaporating the simulant and dried in an oven at 100°C. The residue was cooled in a desiccator for 30 minutes before being weighed to the nearest 0.1 mg until it reached a constant weight. The extractive was calculated in mg/dm^2. Without the sample, the blank was also performed. This demonstration was carried out by IS 9845:1988. The amount of extractive (Ex) was calculated by equation {1}

$$\text{Ex (mg/dm}^2\text{)} = \frac{M}{A} \times 100 \text{ .... } \{1\}$$

Where,
M = mass of residue in mg minus blank value, and
A = total surface area in cm^2 exposed in each replicate

Product quality assessment during storage

Packaged and stored potato chips and biscuits were evaluated for (i) Moisture content and, (ii) Peroxide value. It was determined for 30 days intervals for six months. Moisture content was determined by taking 5 g samples, drying them in an oven at 105±2°C for 2 h according to the ISI handbook of food analysis, and calculated them as shown in equation {2}

$$\text{MC \% by weight } = \frac{100(M1-M2)\times 100}{(M1-M)} \text{ .... } \{2\}$$

Where,
M1 = weight in g of the dish with the material before drying
M2 = weight in g of the dish with the dried material
M = weight in g of the empty dish

The PV was determined by AOAC 965.33 method and calculated using equation {3}

$$\text{PV (meq kg}^{-1}\text{)} = \frac{\text{Titre} \times \text{Normality of thiosulphate solution} \times 1000}{\text{Weight of sample}} \text{ .... } \{3\}$$

Statistical analysis

All treatments were carried out in triplicates. SAS 9.1 was used to analyze variance (ANOVA) on the experimental data (SAS Institute Inc., Cary, NC, USA), which revealed the significance of the study. A significant difference between treatments was determined using Tukey's method at a level of significance ($p < 0.05$). All the data were presented as mean± standard deviation.

Results and Discussion

Food compatibility

OM values for LDPE (T_0) and LDPE-modified corn starch (T_1, T_2, T_3, and T_4) film in n-heptane simulant ranged from 0.12 to 3.94 mg/dm^2 for potato chips and 0.12 to 3.47 mg/dm^2 for biscuits, all well within the 10 mg/dm^2 limit, indicating suitability for food packaging applications, as shown in Tables 1 & 2. Migration is influenced by a variety of factors that can have a direct impact on the extent of migrant and rate as explained by Arvanitoyannis and Bosnea [2]. The substrate with the highest fat content, contact time, and temperature had the highest level of migration into food [6]. Higher migration rates are linked to thinner packages according to Nerín et al., [7]. Tables 1 and 2 showed that the T_4 film samples, which are thicker in size, have a lower migration rate than the other treatments (T_1, T_2, and T_3). Experimental data showed that the rate of migration has increased with storage time. Since fat content influenced the extent of migration rate, the potato chips samples showed higher OM than the biscuit samples. This was in agreement with the studies by Silva et al., [1] revealed that migration increased with fat content. It was noticed that increasing the temperature during the migration study affects the OM rate [8]. The environment temperature raised during the sixth-month migration study, which may have affected the OM rate.

Storage stability monitoring of potato chips and biscuits

Moisture content

The changes in moisture content in packed potato chips and biscuits samples over six months storage study are shown in Tables 3 and 4, respectively. The moisture content of all treatments (T_0 to T_4) ranged from 0.92% to 3.67% for potato chips. According to previous studies, the moisture content should not exceed 2% [9]. Above this, the potato chips lose their texture. Table 3 shows that products packed in biodegradable films (T_1 and T_2) had a moisture content of less than 2% for up to four months. The T_3, and T_4 films, on the other hand, did not yield satisfactory results. All treatments (T_0 to T_4) had moisture content ranging from 1.64% to 6.90% in biscuits. Findings reveal that the moisture content should not exceed 5% [10].

For T_1 and T_2, the moisture content was within the desirable limit up to four months compared to T_0, whereas the T_3, and T_4 samples showed a gradual increase in moisture after three months of storage, indicating that it is unsuitable as a packaging material for biscuits.

Table 1. Food compatibility of LDPE-modified corn starch films containing potato chips

Overall migration (mg/dm²) as per IS: 9845: 1988					
Month	**T_0**	**T_1**	**T_2**	**T_3**	**T_4**
1	$0.12^c \pm 0.01$	$0.56^a \pm 0.032$	$0.53^a \pm 0.026$	$0.45^b \pm 0.035$	$0.41^b \pm 0.02$
2	$0.14^c \pm 0.030$	$0.72^a \pm 0.03$	$0.66^a \pm 0.026$	$0.59^b \pm 0.026$	$0.56^b \pm 0.036$
3	$0.20^e \pm 0.032$	$1.29^a \pm 0.025$	$1.19^b \pm 0.020$	$1.11^c \pm 0.015$	$0.89^d \pm 0.026$
4	$0.25^d \pm 0.026$	$1.56^a \pm 0.036$	$1.48^b \pm 0.026$	$1.42^c \pm 0.02$	$1.4^c \pm 0.01$
5	$0.32^e \pm 0.015$	$2.12^a \pm 0.025$	$2.06^b \pm 0.020$	$1.99^c \pm 0.02$	$1.92^d \pm 0.015$
6	$0.34^e \pm 0.015$	$3.94^a \pm 0.020$	$3.74^b \pm 0.02$	$3.22^c \pm 0.025$	$2.92^d \pm 0.015$

T_0 Virgin LDPE film without modified corn starch;
T_1, T_2, T_3, T_4, - Biodegradable films with 95:5, 90:10, 85:15 & 80:20 LDPE/modified corn starch.
All values shown are means± standard deviations. Limit < 10mg/dm²
Different letters in the rows indicate that there are statistically significant differences ($p < 0.05$) between samples.
Data with the same letter (a-e) within a row are not statistically different at a ($p < 0.05$) level.

Table 2. Food compatibility of LDPE-modified corn starch films containing biscuits

Overall migration (mg/dm²) as per IS: 9845: 1988					
Month	**T_0**	**T_1**	**T_2**	**T_3**	**T_4**
1	$0.12^d \pm 0.01$	$0.47^a \pm 0.02$	$0.42^b \pm 0.025$	$0.38^{bc} \pm 0.015$	$0.35^c \pm 0.015$
2	$0.13^d \pm 0.020$	$0.61^a \pm 0.015$	$0.56^b \pm 0.015$	$0.47^c \pm 0.02$	$0.45^c \pm 0.015$
3	$0.14^e \pm 0.02$	$1.22^a \pm 0.02$	$1.12^b \pm 0.020$	$1.03^c \pm 0.015$	$0.95^d \pm 0.020$
4	$0.19^d \pm 0.015$	$1.24^a \pm 0.02$	$1.21^a \pm 0.01$	$0.92^b \pm 0.015$	$0.83^c \pm 0.020$
5	$0.21^d \pm 0.020$	$1.73^a \pm 0.015$	$1.65^{ab} \pm 0.01$	$1.61^{bc} \pm 0.026$	$1.51^c \pm 0.101$
6	$0.26^e \pm 0.025$	$3.47^a \pm 0.025$	$3.33^b \pm 0.026$	$3.06^c \pm 0.025$	$2.91^d \pm 0.02$

All values shown are means± standard deviations. Limit < 10mg/dm²
Different letters in the rows indicate that there are statistically significant differences ($p < 0.05$) between samples
Data with the same letter (a-e) within a row are not statistically different at a ($p < 0.05$) level

Peroxide value

PV is a measure of fat stability in food and an indicator of its shelf life. PV of potato chips increased from 1.91 to 6.87 meq kg^{-1} from 1 to 3 months, as shown in Table 5 for treatments (control and with T_1, T_2, T_3, and T_4). As per the Food Safety and Standard (Food Products Standards and Food Additives) Regulation, 2011, PV of fats and oil should not be more than 10 milliequivalents/kg oil. The significant increase in PV after 3 months of storage could be attributed to the presence of oxygen that remained inside the package headspace during the packaging process, causing lipid oxidation during product storage. When the storage period accelerates PV increases and similar kinds of observations were noted by Stoll et al., [11] on quality attributes of extra virgin olive oil during storage. During the first month of storage, the PV of fresh biscuits ranged from 1.02 to 3.71 meq kg^{-1}, as shown in Table 6, indicating that the biscuits did not exhibit initial oxidative rancidity. At the end of the third-month storage study, the biscuits started to show the onset of oxidative rancidity which resulted in the gradual increase of PV values. This value was significant when analysed statistically.

Table 3. The moisture content of LDPE-modified corn starch films containing potato chips

Month	T_0 (%)	T_1 (%)	T_2 (%)	T_3 (%)	T_4 (%)
1	$0.92^e \pm 0.025$	$1.22^d \pm 0.02$	$1.49^c \pm 0.01$	$1.78^b \pm 0.02$	$2.08^a \pm 0.02$
2	$0.92^e \pm 0.025$	$1.24^d \pm 0.01$	$1.56^c \pm 0.015$	$2.05^b \pm 0.03$	$2.13^a \pm 0.03$
3	$0.92^e \pm 0.026$	$1.47^d \pm 0.01$	$1.74^c \pm 0.025$	$2.09^b \pm 0.02$	$2.33^a \pm 0.03$
4	$0.92^e \pm 0.02$	$1.76^d \pm 0.02$	$2.05^c \pm 0.04$	$2.17^b \pm 0.02$	$2.77^a \pm 0.02$
5	$0.92^e \pm 0.02$	$1.87^d \pm 0.01$	$2.16^c \pm 0.02$	$2.39^b \pm 0.025$	$2.96^a \pm 0.02$
6	$0.96^e \pm 0.01$	$2.44^d \pm 0.015$	$2.64^c \pm 0.025$	$3.07^b \pm 0.02$	$3.67^a \pm 0.02$

All values shown are means± standard deviations.
Different letters in the rows indicate that there are statistically significant differences ($p < 0.05$) between samples. Data with the same letter (a-e) within a row are not statistically different at a ($p < 0.05$) level.

Table 4. The moisture content of LDPE-modified corn starch films containing biscuits

Month	T_0 (%)	T_1 (%)	T_2 (%)	T_3 (%)	T_4 (%)
1	$1.64^e \pm 0.025$	$2.50^d \pm 0.01$	$3.53^c \pm 0.026$	$3.77^b \pm 0.030$	$4.43^a \pm 0.032$
2	$1.64^e \pm 0.025$	$3.29^d \pm 0.02$	$3.53^c \pm 0.015$	$3.77^b \pm 0.020$	$4.43^a \pm 0.025$
3	$1.64^e \pm 0.025$	$3.32^d \pm 0.030$	$3.47^c \pm 0.02$	$4.53^b \pm 0.01$	$5.08^a \pm 0.015$
4	$1.65^e \pm 0.02$	$3.61^d \pm 0.01$	$4.02^c \pm 0.02$	$5.09^b \pm 0.015$	$5.16^a \pm 0.020$
5	$1.65^d \pm 0.01$	$5.14^c \pm 0.025$	$5.17^c \pm 0.015$	$5.22^b \pm 0.020$	$6.45^a \pm 0.020$
6	$1.66^e \pm 0.005$	$5.44^d \pm 0.025$	$5.68^c \pm 0.015$	$5.81^b \pm 0.015$	$6.90^a \pm 0.020$

All values shown are means± standard deviations.
Different letters in the rows indicate that there are statistically significant differences ($p < 0.05$) between samples.Data with the same letter (a-e) within a row are not statistically different at a ($p < 0.05$) level.

Table 5. PV of LDPE-modified corn starch films containing potato chips

Month	T_0	T_1	T_2	T_3	T_4
1	$1.91^e \pm 0.01$	$3.10^d \pm 0.005$	$3.22^c \pm 0.01$	$3.39^b \pm 0.02$	$3.63^a \pm 0.01$
2	$2.22^e \pm 0.02$	$4.2^d \pm 0.01$	$4.51^c \pm 0.01$	$4.91^b \pm 0.01$	$5.53^a \pm 0.01$
3	$3.24^e \pm 0.01$	$4.91^d \pm 0.02$	$5.25^c \pm 0.01$	$5.85^b \pm 0.01$	$6.87^a \pm 0.01$
4	$6.14^e \pm 0.020$	$10.73^d \pm 0.03$	$12.11^c \pm 0.02$	$14.15^b \pm 0.02$	$16.34^a \pm 0.02$
5	$10.21^e \pm 0.01$	$14.25^d \pm 0.02$	$15.8^c \pm 0.01$	$16.61^b \pm 0.01$	$18.39^a \pm 0.005$
6	$10.46^e \pm 0.02$	$14.68^d \pm 0.02$	$16.01^c \pm 0.06$	$16.94^b \pm 0.02$	$18.69^a \pm 0.03$

All values shown are means± standard deviations.
Different letters in the rows indicate that there are statistically significant differences ($p < 0.05$) between samples. Data with the same letter (a-e) within a row are not statistically different at a ($p < 0.05$) level. PV for all samples was measured in (meq kg^{-1})

Table 6. PV of LDPE-modified corn starch films containing biscuits

Month	T_0	T_1	T_2	T_3	T_4
1	$1.02^{e} \pm 0.02$	$1.45^{d} \pm 0.01$	$2.21^{c} \pm 0.01$	$3.13^{b} \pm 0.15$	$3.71^{a} \pm 0.01$
2	$1.81^{e} \pm 0.01$	$2.21^{d} \pm 0.01$	$3.60^{c} \pm 0.005$	$4.20^{b} \pm 0.005$	$4.91^{a} \pm 0.01$
3	$2.3^{e} \pm 0.01$	$2.80^{d} \pm 0.005$	$3.90^{c} \pm 0.005$	$4.31^{b} \pm 0.015$	$5.81^{a} \pm 0.01$
4	$3.60^{e} \pm 0.005$	$4.21^{d} \pm 0.01$	$7.80^{c} \pm 0.005$	$9.21^{b} \pm 0.015$	$10.60^{a} \pm 0.005$
5	$8.20^{e} \pm 0.005$	$10.51^{d} \pm 0.01$	$14.25^{c} \pm 0.01$	$15.82^{b} \pm 0.02$	$16.95^{a} \pm 0.01$
6	$10.24^{e} \pm 0.015$	$10.76^{d} \pm 0.020$	$15.57^{c} \pm 0.015$	$15.94^{b} \pm 0.026$	$16.95^{a} \pm 0.025$

All values shown are means± standard deviations.
Different letters in the rows indicate that there are statistically significant differences ($p < 0.05$) between samples. Data with the same letter (a-e) within a row are not statistically different at a ($p < 0.05$) level. PV for all samples was measured in (meq kg^{-1})

Conclusion

In terms of OM, biodegradable films can be used as a food packaging material. Reliable migration data were analyzed, and it demonstrated compatibility with food products while adhering to legislation and food safety standards. During a product storage study, it was revealed that biodegradable films (T_1 and T_2) can be used as a packaging material for biscuits, while potato chips were found to be in good condition for up to three months. It is possible to conclude that biodegradable films T_1 and T_2 could be used as food packaging material for various food products.

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Conflict of Interest

The author declares that in the current study there is no conflict of interest.

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