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Study on the Effective Reduction of Oil Up-Take by the Application of Edible Hydrocolloid Coatings on French Fries

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Abstract

French fries are a very popular snack food made from potatoes. These are prepared by deep fat frying method therefore it a high oil content food. Such foods are a major concern for health. The trend that is now being followed is to meet the consumers' demand for low-fat food. Studies have been conducted using edible coating and films as barriers to the incorporation of oil during frying. In the present study efforts have been made to evaluate the water retention and fat reduction capability based on different parameters of the different hydrocolloids coatings. Pectin, sodium alginate, guar gum and a mixture gum of sodium alginate and guar gum at different concentrations were used as the coating material. The moisture content as well as fat content was measured. Other parameters like water retention, water loss during frying, decrease in water loss, fat uptake, decrease in fat uptake and the index values were calculated to know the overall impact of the hydrocolloid coating materials used. Textural and colour changes in fried French fries were followed by the parameter shear force and L*, a*, b* values. From the studies it emerged that by using hydrocolloid edible coating that was an effective reduction in the fat content. It was also observed that by using coating the texture and colour of the coated samples did not much differ from the non-coated control sample.

Keywords: *hydrocolloid edible coating, deep-fat frying, French fries, oil uptake, water retention.*

1. Introduction

Potato is one of the most important crops. It ranks 3rd in the order of importance in India. In order of importance for food production, potato rank, 6th in the developing countries, 4th in the developed countries, 4th in all world. Fresh potatoes can be processed into several value added fried and non-fried products having long shelf life. The demand for processed potato products like chips and French fries is increasing continuously in the present day mainly due to improved living standards, urbanization growth, preference of new generation for fast foods, rise in per capita income etc.

In the recent years there is an increase in the consumption of fried foods. Fats and oils greatly attribute to the sensorial properties of food and hence are in great demand. Fried foods have a very high fat content. This increase has a detrimental effect on the health of the consumers. High consumption of such fatty foods leads to obesity, high cholesterol and causes a series of heart problems. These health issues should be tackled and awareness among the consumers should be increases. During the past 10 years, the American Heart Association and other health organizations have encouraged reduction of fat from food to less than 30% of calories for most people (USDA 1990, USDA & USDHHS 1990).

To address these problems a series of studies are being done to prepare food with very low or no oil content. A number of ways are explored for this purpose. These include use of pre-drying before frying, frying under high temperature and short-time conditions, and use of an edible film as coating agent [Krodika et.al., 2001, Khalil 1999, Rayner et.al., 2000]. Thus, reducing the fat content of fried foods by application of coatings is an alternative to comply with both health concerns and consumer preferences.

Edible coatings consist of hydrocolloids, lipids, or even composite of these. Hydrocolloids have grabbed a lot of interest because they possess good barrier properties to oxygen, carbon dioxide and lipids [Mallikarjunan et.al., 1997, William and Mittal 1999]. Applicable hydrocolloids include proteins, cellulose derivatives, alginates, pectin, starches, and other polysaccharides.

Deep fat frying is a dry cooking process it involves the immersion of food pieces in hot vegetable oils [Moyano et.al., 2002]. This process is used for the preparation of special foods which have an internal soft structure with a fragile and tender crust [Garcia et.al. 2002] to keep flavor of food inside it [Moyano et.al. 2002].

In the deep fat frying process, simultaneous occurrence of heat and mass transfer takes place. When food particles are added to the hot oil, the surface temperature of the food particle increases. This leads to the loss of surface water due to evaporation and thereby causing surface shrinkage and surface drying. Due to the evaporation of the surface water the pressure gradient inside the food particles is created. Due to this pressure gradient in the capillary tubes and inside surface channels water from the central points of the food is pumped to its surface and this leads to the evaporation of the water at surface during frying.

There are many works in the literature on reducing the oil uptake by coating. R William et.al., 1999 did studies on edible coating by mathematic modeling . A model was developed on the heat, mass and fat transfer.

Susanne Albert et.al., (2001) studied eleven hydrocolloid materials including gelatine, gellan gum, k-carrageenan-konjac-blend, locust bean gum, methyl cellulose (MC), microcrystalline cellulose, pectin (three types), sodium caseinate, soy protein isolate (SPI), vital wheat gluten and whey protein isolate (WPI) were compared for their film forming ability, suitability for fried foods, and water and fat transfer properties. The effect of these coatings were studied at various formulation on products formed from pastry mix. Study showed that there was decrease in the oil absorption in comparison to blank sample.

Khalil (1999) studied the effect of different coating material on the French fries. Studies were made by using calcium chloride along with pectin and sodium alginate at six different concentration levels. Second and third coatings were also applied. It was observed that the best reading was obtained for samples with second coating. 0.5% calcium chloride gave the best results.

Yadav et.al., (2011) incorporated fiber in puries so that reduction in the oil uptake can take place and the optimization for the fiber incorporation was also done in accordance with acceptability of the product. Their results showed that there was significant ($p \leq 0.5$) positive effect on the moisture retention and negative effect on the fat absorption due to the addition of oat bran.

Daraei Garmakhany et.al (2008) studied that there was reduction in the oil content and well as improvement in the quality of the chips due to the application of coating materials. The materials used for the study were pectin guar gum and CMC solution.

2. Materials and Methods

2.1 Materials Required

Potato tubers (Solanum tuberosum) were purchased from the local markets of Allahabad, India. Prior to experimental work out the potatoes were kept at room temperature. Refined soybean oil was purchased locally. The food grade coating materials were acquired locally.

2.2 Sample Preparation

The potato tubers were washed with tap water, peeled using potato peeler, and cut into strips of 1*1*6 cm dimension with the help of manually operated French fry cutter. For the control sample the French fries blanched in only water without any chemical treatment at the temperature of 85^{o}C for 5mins and then washed in cold water for the same length of time. The control strips were then dried at 150^{o}C for 5±5 minutes using tray drier. The rest of the samples were blanched in 0.5% aqueous solution of $CaCl_2$ at the temperature of 85^{o}C for 5mins and then washed in cold water for the same length of time. These were then partially dried to remove the excess water. These strips were then dipped in the coating solutions. They were immersed in the coating solutions for 5mins. After coating the strips were dried at 150^{o}C for 5±5 minutes using tray drier.

The coated and the uncoated samples were fried in a deep fat fryer with thermostats having a capacity of 10 litres of oil. The temperature was maintained at 175 ±10 ^{o}C for 90 seconds. After each frying the oil level were replenished. The samples were then cooled and packed and kept was physiochemical tests.

Hydrocolloid solution for coating the samples were prepared. Three coating material were used these are pectin, sodium alginate, guar gum. These were acquired from the local market of Allahabad. Solutions of three concentrations (2%, 4%, and 6%) were prepared for each material. Three mixture coatings of sodium alginate and guar gum at different percentage were also prepared. These concentrations were 0.5%+0.5%, 1%+1%, 2%+2%. The required concentration was prepared by measuring the required quantity and dissolving the coating powder in hot distilled water (temperature of the distilled water depends on the property of the coating powder). The solution is continuously stirred and cooled to room temperature and to it the samples were added. The gums used were selected on the basis of its availability and cost of the gum.

2.3 Analytical methods

2.3.1 Moisture Content (%) (By AOAC)

Standard procedure of AOAC, 1984 was followed to estimate the moisture content of raw French fries and fried French fries. The moisture content (MC) was determined by weight loss of the fried products, upon drying in an oven at 105 ^{O}C until a constant weight was reached.

$$\text{Moisture Content \%} = \frac{\text{Difference in dry weight}}{\text{Weight of the sample}} \times 100 \quad \text{(I)}$$

The relative increase of water retention % (WR) in the coated product relative to the uncoated one was calculated as follows:

$$WR = \frac{(\text{MC after coating} - \text{MC before coating})}{\text{WC before coating}} \times 100 \quad \text{(II)}$$

where WC after coating and WC before coating are the water contents of the coated and uncoated samples, respectively. For each coating formulation, results were obtained using all samples from at least three different batches.

2.3.2 Fat content % (Soxhlet method)

The fat content (FC) of the fried products was determined on dried samples using continuous Soxhlet extractions. The extraction time was 16 hours.

The oil uptake decrease % (OU) in the coated product relative to the uncoated one was calculated as follows:

$$OU = \frac{(\text{FC after coating} - \text{FC before coating})}{\text{FC before coating}} \times 100 \quad \text{(III)}$$

2.3.3 Effect on Moisture & Fat Transfer

This work is for the identification of a coating material at a particular concentration that can reduce the fat uptake but also maintain the water content of the sample. So the fat and moisture content data were compared on the basis of the calculation of the fat reduction, water loss, fat uptake reduction and an index value was also calculated. [Garcia et.al., 2002]

Fat reduction due to coating, in the coated product relative to the uncoated one was calculated as follows:

Fat reduction due to coating

$$= \frac{\text{FC (after coating)} - \text{FC (before coating)}}{\text{FC (before coating)}} \times 100 \quad \text{(IV)}$$

Where FC- coated and FC- uncoated are the lipid contents of the coated and uncoated samples respectively. For each of the coating, the results were obtained in triplicates.

Water loss during frying

$$= \frac{(\text{initial water} - \text{water after frying})}{\text{Initial water}} \quad \text{(V)}$$

Decrease in water loss due to coating

$$= \frac{((\text{water loss; non-coated}) - (\text{water loss; coated}))}{(\text{Water loss; non-coated})} \quad \text{(VI)}$$

Fat uptake

$$= \frac{(\text{Final fat content x mass after frying}) - (\text{initial fat content x mass before frying})}{\text{Dry mass}} \quad \text{(VII)}$$

Reduction of fat uptake due to coating

$$= \frac{((\text{fat uptake; non-coated}) - (\text{fat uptake; coated}))}{\text{Fat uptake; non-coated}} \quad \text{(VIII)}$$

$$\text{Index} = \frac{\text{reduction of fat uptake}}{\text{Decrease of water loss}} \quad \text{(IX)}$$

2.3.4 Coating Pick-up

Coating pick-up was calculated from the difference between coated weight and non-coated weight of raw potato sample. It can be formulated as in equation X [Parinyasiri et.al., 1991];

$$\text{\% Coating Pick – up} = \frac{(F - I)}{I} \times 100 \quad \text{(X)}$$

Where;

F= weight of raw coated French fries
I= initial weight of raw non-coated French fries

2.3.5 Frying yield calculations

Percentage of frying yield was obtained by considering the weight of the fried French fries and the raw French fries after coating. It can be formulated as equation XI []Parinyasiri et.al., 1991];;

$$\text{\% Frying Yield} = (CW/NCW) \times 100 \quad \text{(XI)}$$

Where;

CW= cooked weight of coated French fries
NCW= weight of non-cooked coated French fries

2.3.6 Colour Measurement

The colour changes in the coated and non-coated control samples were measured. The colour parameter used is Hunter L, a, b. L, a, b type of scales simulate this as:

• L (lightness) axis—0 is black, 100 is white;
• a (red-green) axis—positive values are red; negative values are green and 0 is neutral; and
• b (yellow-blue) axis—positive values are yellow; negative values are blue and 0 is neutral.

2.3.7 Texture Measurement

Texture of coated and uncoated potato strips were measured by use of TA.XT plus Texture Analyser of the Mason Technologies. Shear forces for the samples were measured. Shearing force was formulized as below equation:

$$\text{Shearing force} = \frac{F}{2\pi r2} \qquad \text{(XII)}$$

Where; F was the required force for cutting the cylindrical potato strips and r was the potato samples radius. Triplicate readings were carried out at room temperature on the center point of each slice

2.3.8 Statistical Analysis

All these experiments were replicated three times, and the average values were reported. The effects of different concentrations of hydrocolloid coating material on French fries were determined using the analysis of variance (ANOVA) method.

Table 1: Effect of Coating on Moisture and Fat content of the French fries

Coating Formulation	Fat content[%]	Moisture content[%]	Dry matter Content[%]	WR [%]	OU [%]
Control	24.707	21.70	78.30	-	-
Pectin 2%	15.859	22.80	77.20	5.07	35.81
Pectin 4%	11.753	31.01	68.99	42.90	52.24
Pectin 6%	9.700	35.95	64.05	65.67	60.73
Sodium alginate 2%	14.667	25.46	74.54	17.33	40.63
Sodium alginate 4%	15.210	27.60	72.40	27.19	38.44
Sodium alginate 6%	13.504	22.65	77.35	4.37	45.34
Guar gum 2%	14.823	29.25	70.75	34.79	40.00
Guar gum 4%	15.225	31.15	68.85	43.55	38.38
Guar gum 6%	11.559	33.70	66.30	7.16	55.23
Mixture 0.5%	13.867	24.80	75.2	14.29	43.87
Mixture 1%	13.225	28.25	71.75	30.18	46.47
Mixture 2%	12.742	28.42	71.60	30.97	48.43

3. Results and Discussion

Table 1 shows the moisture content and water retention of the coated and the uncoated samples after frying. Results showed that there was an overall increase in the moisture content and water retention. From the result it was observed that the maximum moisture content was in pectin with concentration of 6% whereas sodium alginate with a concentration of 6% showed the lowest moisture content. The pectin and guar gum films showed the maximum moisture content in the sample; similar results were obtained for the mixture coatings also. In case of sodium alginate uniform results were not obtained. Pectin coatings showed the best efficiency of the edible coatings in case of increasing the moisture content of the samples. Same results were observed for water retention. The maximum water retention was observed in pectin 6% while the least was observed in sodium alginate 6%. It is seen that hydrocolloid coating had significant (p<5) effect on the moisture content of the samples.

In the final product due to coating there was an increase in the moisture content. The coated samples showed an increase in moisture then the non-coated sample. The results obtained were in agreement with the works of Khalil (1999), Williams and Mittal (1999), Daraei Garnakhany et.al. (2012). The hydrocolloid gums that are applied on the samples acts as barrier material thereby not allowing the water to rise on the surface and leave the sample. Gums are hydrophilic in nature; due to this property it limits the permeability of moisture. This is the reason why coated samples have more moisture then compared to the non-coated samples.

From the results obtained it was also observed the level of moisture content in each coated sample is different. This difference in the moisture content is due to the property of the individual coating material (William et.al., 1999, Balasubramaniam et.al., 1997, Sakhale et.al., 2011). The concentrations of the coating materials also affect the amount of water retention taking place. It was seen that with the increase in the coating concentration there was an increase in the moisture content. Similar pattern of readings were obtained by Daraei Garmakhany et.al. (2008).

The results clearly showed that there is a marked decrease in the oil content as compared to control with coated samples. From the results obtained it was observed that pectin with concentration of 6% was observed to have the least amount of fat content whereas guar gum and sodium alginate with concentration of 4% have the maximum amount of fat content.

The absorption of oil in the sample takes place in 2-steps. Maximum amount of oil is absorption takes after the samples are removed from the oil. Absorption of oil on the surface takes place when the samples are removed from the frying medium, the remaining oil enters into the product (Ufheil et.al., 1996, Aguilera et.al., 2000). Observations have been made by Moreira, Sun, & Chen, (1997) regarding the oil uptake was that 20% of the oil uptake takes place during the deep fat frying while the 80% takes place after the food material is removed from the fat. 64% of the oil uptake takes place when the food materials are cooled. Another factor governing the amount of the oil uptake is the condition under which the food samples are removed. This is due to the surface adhesion of the oil, and the draining phenomena. Two main mechanisms mainly explain the oil uptake process: condensation and capillary mechanisms, in both cases the oil penetrates through the pores in the food samples (Mellema, 2003). So it is important that the pore sizes and quantity in the samples are reduced. The can be achieved by the application of hydrocolloid coating on the food samples.

As the main purpose of coating was to reduce the fat content of the final product the result obtained were satisfactory and showed that coating had significant (p<5) effect on the fat content of the coated French fries and follow the same trend with the results of those of Khalil [1999], Garmakhany et.al [2012].

The greatest oil reduction was observed in pectin with a concentration of 6% followed by guar gum with concentration of 6%. The least oil reduction was observed in pectin 2%. All the hydrocolloid coating materials had a significant reduction in the oil content in the tested samples. This provided success to the experimental plan that was followed.

The differences in these values are again due to the difference the properties of the coating materials used which have different properties which governs the moisture retention in the test samples. The hydrocolloids form a matrix on the samples and thereby preventing the loss of moisture and not allowing the entry of the oil through capillary action during frying.

From the results obtained from experimentation it was observe that there was considerable decrease in the loss of water during frying when the coated samples were compared with the uncoated control sample. It was observed that pectin with concentration of 6% had the least amount of water loss of 0.260 and the maximum amount of water loss was observed in sodium alginate with concentration of 6% which was about 0.672. Low water loss was also observed in the guar gum. Whereas sodium alginate and mixture gum did not show much reduction in the water loss. Results are given in Table 2.

From table 2 maximum decrease in water loss due to coating was observed in pectin with concentration of 6% followed by pectin with 4% concentration. Guar gum with concentration 6% also showed a marked decrease in water loss. Minimum decrease was observed in sodium alginate of all concentrations.The lowest fat uptake was observed in pectin with 6% concentration as well as in guar gum with the concentration of 6%. The sample having the maximum fat uptake were control samples, sodium alginate with coating concentration of 2% and mixture coating of concentration of 0.5%.

Reduction in fat uptake is the reduction in the amount of fat in the hydrocolloid coated samples. It is observed from the table that the guar gum with the concentration of 6% showed the maximum reduction in the fat uptake. The coating formulation that showed a marked reduction in the fat uptake is pectin with concentration of 6%. The minimum reduction was observed in coatings with sodium alginate and mixture gum. Sample coated with sodium alginate with a concentration of 2% and mixture gum with the concentration of 0.5% had the least value of fat uptake reduction.

Pectin with the concentration 6% has the maximum water content while having a minimum fat content. This is reflected in the index factor of pectin 6%. While the minimum index factor is of that of sodium alginate with the concentration of 6%. A high index value was also observed for guar gum with concentration of 6%. From the index value it can be said that the pectin with 6% concentration, guar gum with 6% concentration are better coating materials compared to the rest. While sodium alginate with 6% concentration can be said to be the least acceptable coating material for this purpose.

Table:- 3 coating pickup and frying yield of french fries

Coating formulation	% Coating pick-up	Frying yield %
Control	--	66.05
Pectin 2%	4.2	44.47
Pectin 4%	5.0	46.99
Pectin 6%	5.3	58.95
Sodiumalginate 2%	3.4	46.00
Sodium alginate 4%	3.9	47.55
Sodium alginate 6%	4.4	58.55
Guar gum 2%	5.9	44.42
Guar gum 4%	7.4	53.97
Guar gum 6%	9.2	47.10
Mixture 0.5%	4.7	44.07
Mixture 1%	5.3	57.09
Mixture 2%	5.5	43.24

Coatings are used in deep fat frying as the improve appearance, flavor and texture reducing dehydration, aiding browning and also gives a crisp texture the fried parts (Sanderson 1981). Coating pick-up is the amount of coating that is placed on the sample when immersed in the solution.

The different coating pickups are given in Table 3. It shows that the coating pick-up of guar gum 6% is the maximum that is 9.2% whereas the least was observed in sodium alginate 2% which is 3.4%.

It can be noted from the table that with the increase in the concentration of the coating materials the coating pick-up percentage also increased in most cases. This may be attributed to the differences in adequate concentrations of coating formulations, among other causes, to differences in adhesion between substrate and coating suspension, surface characteristics of the sample and frying conditions (Draei Garmakhany et.al., 2008)

The yield percentages of the coated and non-coated samples are given in the table 4.8. From the data obtained it was observed that the highest frying yield is that of the control followed by pectin with the concentration of 6% followed by sodium alginate with the concentration of 6%. The lowest frying yield was that of the mixture 2% as well as that of Guar gum 2%.

The colour parameters L*, a* and b* of the samples after frying of the coated and the control sample are given in the chart 2. From the data obtained it can be said that regarding colour, the highest L value was observed in coated samples with 6% guar gum followed by Sodium alginate with the concentration of 6% and guar gum with the concentration 2% while the lowest L value was related to coated samples with 0.5% mixture. Other gums didn't have a great variation in the lightness L value compared with uncoated samples which was in agreement with the results of Daraei Garmakhany et al. [2012] and Khalil [1999]. Both concentrations of guar gum had a high a value which increased with increase of concentration in most case. For pectin coated samples, by increasing pectin concentration, the chromaticity a value also increased. The highest and lowest a value was observed respectively for control and mixture samples. The chromaticity b value was highest in guar gum 6% and the lowest in the pectin 2% Since there is no difference between coated and uncoated samples in terms of colour values in most of the cases, it can be concluded that single layer coating with mentioned gums is favourable for commercial production of French fries, but the final selection of coating agent must be done according to the influence of coating gums on oil uptake, texture and other quality attributes of French fries in addition to colour.

The force at which the probe penetrates the outer layer of the food sample is the maximum force required to break that sample. Chart 1 shows the breaking force of the samples with and without coating materials.

It was observed that in most cases, there was an increase in the force required to puncture the samples with the application of the different coating samples. The shear force calculated showed that, force required is slightly greater for the coated sample then for the non-coated samples. So in most cases the textures of the samples were very similar to the control sample. The shear force data indicates that French fries coated with sodium alginate with the concentration of 4% has the minimum shear force while when the samples are coated with pectin with the concentration of 2% has the maximum shear force. So by texture analysis it could be said that the product may find its acceptability among consumers. The firm characteristics of the coated samples can be attributed to the formation of rigid cross-linked network that increases middle lamella-cell wall rigidity and forms a resistant film on the surface of the sample (Khalil 1999). Studies by Rovedo et.al. [1999], Olenick and Kulp [1993] have shown that the final texture of the fried product is slightly dependent on its composition.

From the studies the compatibility of the hydrocolloid coating materials were identified. For all the coating formulations used it was observed that there was an increase in the moisture content in the samples. It was also observed that there was a decrease in the fat content in the samples as compared to the control sample. Pectin with the concentration of 6% showed high moisture content and low fat content in the formulation.

Other coating formulations which show low fat content were pectin with concentration of 4% and guar gum with concentration of 6%. There is not much marked difference in the colour and texture of the coated samples with the control sample it may be said that it will have acceptability by the consumers. So it may be concluded from the results obtained that pectin with the concentration of 6% is a good hydrocolloid in comparison with the other hydrocolloids used in the studies.

4. Conclusions

Table 2:- Fat and moisture transfer through edible coatings in a product during frying

Coating formulation	*Water loss during Frying*	*Decrease in water loss due to coating*	*Decrease in fat uptake*	*Fat uptake*	*Index vale*
Control	0.676	--	-	15.12	0
Pectin 2%	0.620	0.083	0.259	11.20	3.13
Pectin 4%	0.458	0.322	0.367	9.57	1.14
Pectin 6%	0.260	0.615	0.589	6.21	4.67
Sodium alginate 2%	0.659	0.025	0.026	14.73	1.04
Sodium alginate 4%	0.614	0.092	0.137	13.05	1.49
Sodium alginate 6%	0.602	0.074	0.206	12.01	2.79
Guar gum 2%	0.604	0.106	0.375	9.45	3.54
Guar gum 4%	0.585	0.135	0.236	11.55	1.75
Guar gum 6%	0.527	0.220	0.602	6.01	4.27
Mixture 0.5%	0.655	0.031	0.022	14.78	0.71
Mixture 1%	0.625	0.075	0.127	13.20	1.69
Mixture 2%	0.610	0.098	0.232	11.61	2.37

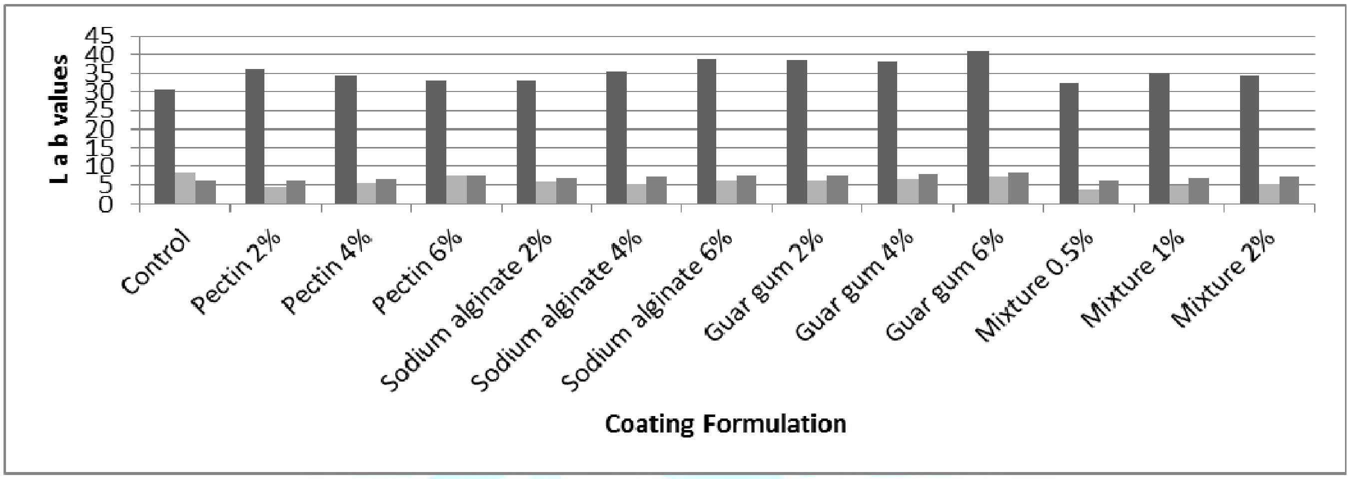

Chart 1: - Hunter L* a* b* reading for different coating formulations

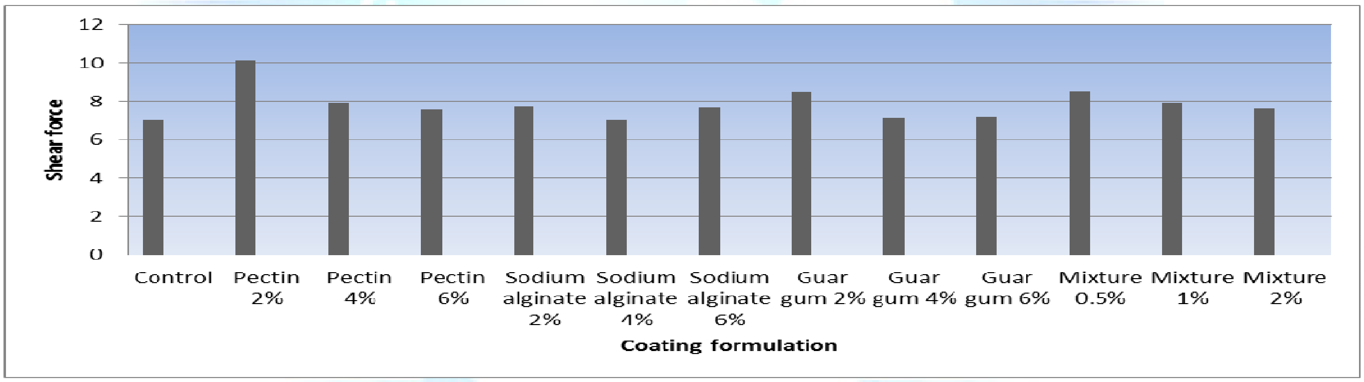

Chart 2:- Shear Force on the French Fries Due To Different Coatings

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