This is to certify that the

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DEVELOPMENT OF A MANUFACTURED POTATO PRODUCT

presented by

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Jerry N. Cash
Major professor

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DEVELOPMENT OF A MANUFACTURED POTATO PRODUCT

By

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ABSTRACT

DEVELOPMENT OF A MANUFACTURED POTATO PRODUCT

By

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Small, extra large and off- grade"Superior"and"Atlantic"potatoes which normally would not be processed were used in developing a precooked, ready-to-serve simulated baked potato product.

The potatoes were extruded in a Baker Perkins twin screw extruder. Following processing, sensory evaluations for interior color, skin color, texture, and flavor were done in order to determine the acceptability of the product by the consumer. Analysis of the sensory evaluation data indicated a high degree of acceptability for the factors rated by the panelists.

The potato product was stored frozen for seven months in two different packaging materials (2 mil low density polyethylene bags, and 6 mil laminated retortable pouchs) and unpackaged. The changes in moisture content of both skin and interior, color and texture profile analysis (TPA) were studied during the storage time. The data showed that the physical deterioration of the potato product was delayed by individual packaging in moisture resistant polymeric film. The data also showed no significant differences in properties between the potato product packaged in low density polyethylene and the one packaged in the laminated retortable pouch.

DEDICATION

To my father and the soul of my mother

God bless her.

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to all the people who have helped me throughout my graduate study. To my major professor, Dr. Jerry N. Cash, for his guidance, encouragement, and support, for which I'll always be grateful. To Dr. H. Lockhart, who improved my knowledge in the area of food packaging. To Dr. R. Y. Ofoli, for his guidance during my work with the extruder. To Dr. P. Markakis, who supported my efforts with grace and sophistication. And to Dr. J. Kelly, for his serving as a member of my guidance committee. A special thanks to Dr. John Gill for his great guidance during the statistical analysis.

Above all, my special gratitude and appreciation go to my my two sons Hatem and Khaled for their love, understanding and unending support.

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DEVELOPMENT OF A MANUFACTURED POTATO PRODUCT

INTRODUCTION

Potatoes (Solanum tuberosum L.) are considered one of the most important vegetables in the world in both total production and nutritional value. Among the total potato crop produced in the United States, a large percentage is commercially processed (Davis et al., 1983). Michigan potato production is an economically important segment of the state's agriculture. Every year a portion of the potato crop is graded into small, extra large or off-grade classes. Some of these tubers may find acceptance in certain types of processed products but this is usually minimal. Since this part of the crop represents significant quantities of raw product, economics dictate that these potatoes be utilized in some other manner. However, without processing alternatives, a majority find their way into thefresh market and this results in lowering the consumer's perception of Michigan potato quality, with attendant losses in sales and revenue. Therefore, it is important that a new processed product be developed which can utilize that portion of the potato crop which is not suited for use in presently established processed products.

The primary objective of this study was to develop a precooked, ready-to-serve potato product which could be used as a simulated baked potato with a uniform size and shape and serve as a substitute in restaurants or institutional food service operations.

LITERATURE REVIEW

Extrusion technology has been applied to a number of food products. Harper(1981) indicates that, the early food extruders were used by the meat industry and in the manufacturing of macaroni. General Mills, Inc. used the extruder to produce ready-to-eat cereals, which were cooked and formed continuously with a one-step process . Presently the extruder is being used to produce a variety of food products like precooked modified starches, ready-to-eat cereals, snack foods, breading substitutes, beverages bases, soft-moist and dry pet food, confections, and soups.

Extruded foods and cereals, which are primarily starch, represent an important and expanding area in food processing. The extruder plays several important functions in the processing of these foods. These functions include cooking and gelatinization of the starch, giving the food a desired shape and texture. Jadhav et al.(1976) studied the relationship between some physicochemical properties of dehydrated potato granules and their stability for extruded French fries. They found that they could produce good quality extruded French fries by using these granules with a mixture of binders such as guar gum, stabilized high amylose corn starch, crosslinked pregelatinized corn starch, and hydroxypropyl-methylcellulose.

Extrusion processed potato snacks, which are generally made from dehydrated potatoes, have captured large segments of the market. These potato snacks have been made by rehydrating the potato flakes followed by extruding, sheeting, stamping, and deep frying (Maga and Cohen, 1978). Nonaka et al. (1978) produced fabricated French fries by extruding a mixture containing 90% dehydrated potato. These fabricated French fries were a competitor to the fries made from raw potatoes because their composition could be controlled, eleminating variations of palatability, quality and frying time.

The extruder can also be used in studying changes in the physical properties of starch during processing. Kim and Hamdy (1987) used high pressure extrusion in order to evaluate the degradation of potato starch, and they found that the significant decreases in viscosities of starch solutions were due to depolymerization of the starch molecules into smaller fractions.

Texture of cooked potatoes is considered to be one of the most important quality factors for consumer acceptance (Davis et al., 1983). Kuhn et al. (1959) found that the processing quality of cooked potato tubers was usually judged by the texture. It is generally agreed that good quality boiled, mashed, and baked potatoes should have a mealy texture.

Ruth and Work (1981) used sensory panel methods to evaluate the quality of baked potatoes grown in Ontario with others grown in Maine and they found that tubers of the Ontario variety were considered less desirable for table stock due to the low mealiness and grayness of flesh. The textural quality of potatoes has been studied by many investigators (Tourneau et al., 1962 ; Bettelheim and Sterling, 1954).

Leung et al.(1983), evaluated the texture of cooked potatoes by sensory evaluation, and texture profile analysis (TPA). They found that there is a correlation between the hardness by the sensory evaluation and the hardness by the TPA.

Davis and Dixon (1976) evaluated potato texture by using taste and appearance of tubers. They found a high correlation between the results obtained by the two methods and they concluded that visual ratings can provide a relatively precise method of judging mealiness in potato tubers.

MATERIAL AND METHODS

1-Manufactured simulated baked potatoes:

Peeled, diced potatoes of the cultivars "Superior" and "Atlantic" were steamed at atmospheric pressure for three minutes prior to processing. This steaming was carried on in order to:

Capture free water by the starch in the tubers.

Inactivate oxidative enzymes.

Partially cook the potatoes prior to extrusion.

The steamed potatoes were then cooled in cold water and 7% by weight of non-fat dry milk powder was added to the cooled steamed potatoes to act as a binding agent. The mixture then was fed into a Baker Perkins twin screw extruder. The general operating parameters for the extruder had been previously determined but the final specific operating conditions were obtained by trial and error during several preliminary runs in the extruder . Table 1 describes the optimum conditions used in operating the extruder. These include items such as the setting and actual temperature for each zone, feed set, screw speed, and the final product temperature. Figure 1 shows a diagram of the twin screw extruder and its different zones. Figure 2 outlines the processing steps for the remanufactured simulated baked potatoes.

Reformation of the potatoes.

The product coming from the extruder die (residence time 45 sec.) was filled through a hole into a plastic mold (Fig.3) that looked like an average, oblong potato.

Development of the potato skin.

The potatoes in the mold were frozen in order to facilitate removing the product from the plastic molds, then dipped in a mixture of 200 gm wheat flour,

Table - 1, The optimum extruder conditions used in manufacturing simulated baked potato product

Screw (RPM)	(MTR.) load (%T)	Feed set lb/Hr.	Heating medium temperatures (set/actual) ^{0}F									Product temperature in each zone ^{0}F					(T) die ^{0}F	Die press. (PSIG)
			Z_1	Z_2	Z_3	Z_4	Z_5	Z_6	Z_7	Z_8	Z_9	1 6	2 7	3 8	4 9	5 10		
200	7	90	+0	100	140	140	140	160	140	140	140	77	119	131	140	151	139	20
			++71	104	140	138	141	159	145	140	140	151	120	144	143	128		

\+ Temperature setting.
++ Actual temperature in designated zones.

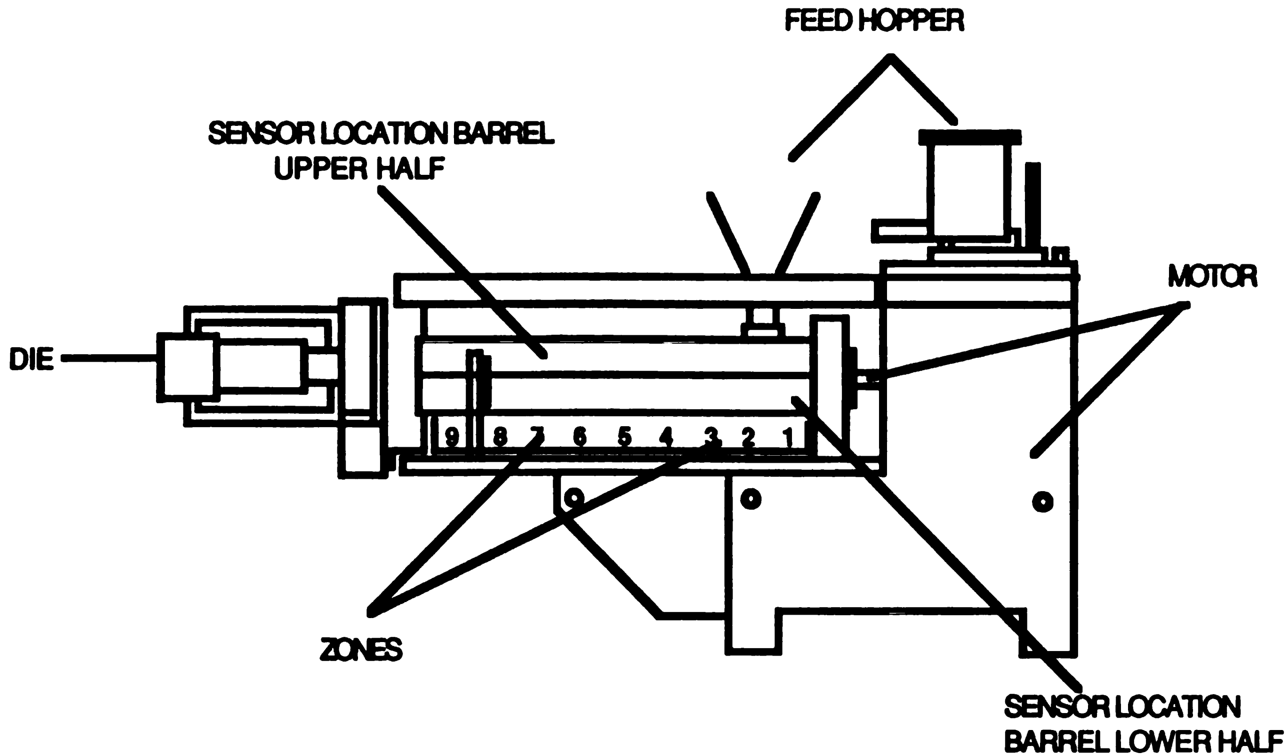

Fig.1. Diagram of MPF-50 D/25 Twin screwe food extruder.

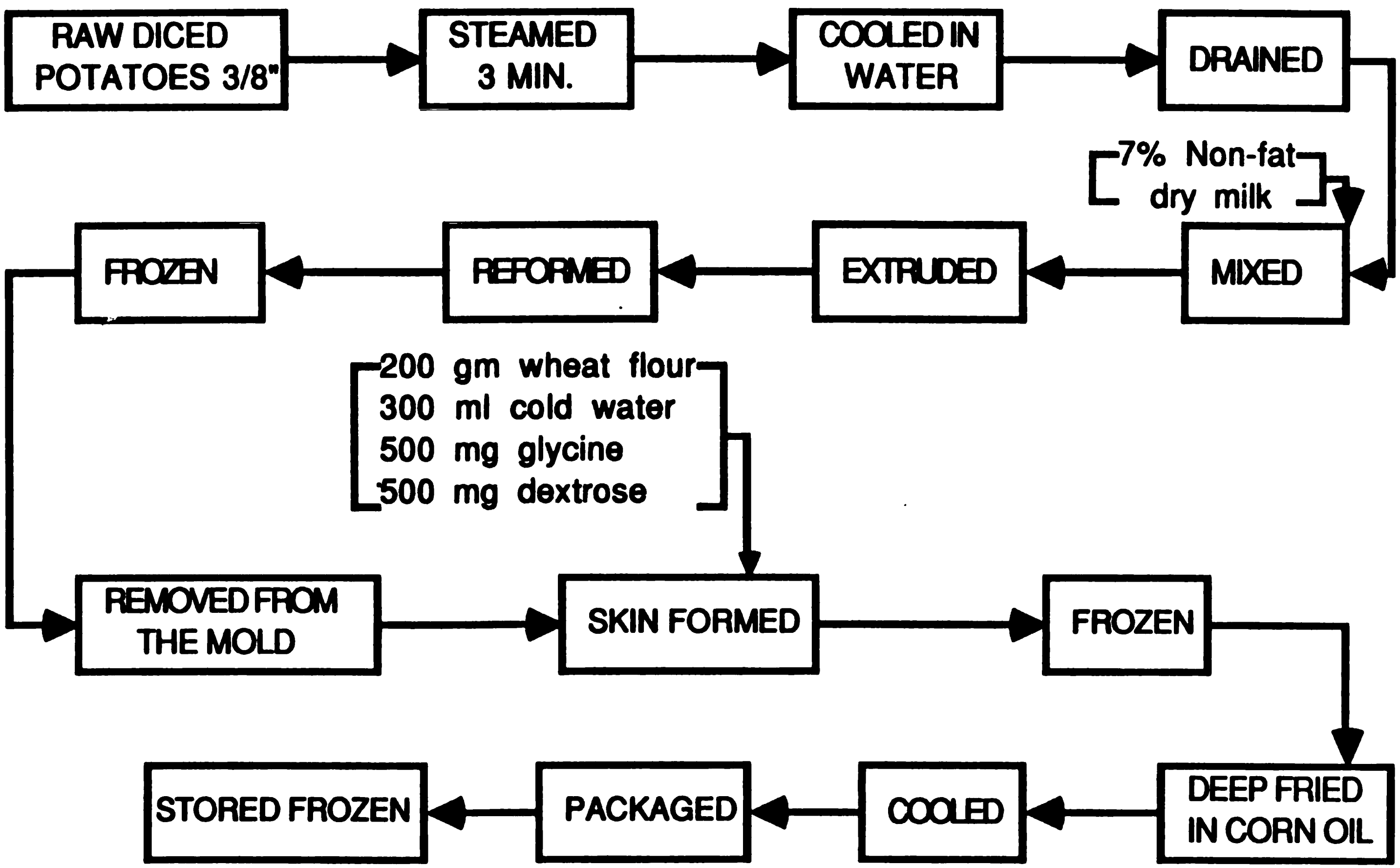

Fig.2. Schematic outline of the processing of simulated baked potato product.

Fig.3. Plastic mold used in reforming the potato product.

300 ml cold water, 500 mg glycine and 500 mg dextrose which was used to form a skin for the potatoes.

The frozen reformed potatoes were dipped in the batter for 1-2 minutes to make sure that a thin layer of the batter covered each individual potato, then the potatoes were frozen again before deep frying in corn oil at 360^0F for 3 minutes to develop the skin texture and color (the crust developed after one minute, whereas the preferable color was obtained after two more minutes). Figures 4, 5, and 6 show the reformed potato product after being removed from the plastic mold, after being covered with flour batter, and after being deep fried respectevely. After frying, the potatoes were stored in the freezer before sensory evaluation and packaging took place.

II- Sensory evaluation of the consumer acceptability:

A- Sensory method.

Sensory evaluation for the color (skin and interior), texture, and flavor were done on the simulated baked potatoes shortly after processing in order to determine consumer acceptability. A non-numerical hedonic scale which ranged from excellent to extremely poor was used for sensory evaluation (Larmond,1977.).

B- Sample preparation and presentation for sensory analysis.

The frozen simulated baked potatoes were cooked in a microwave oven for three minutes, then they stood for one minute outside the oven before they were presented to the panelist. Each panelist examined one sample, and was provided with salt to be used if desired.

C- Judges.

Sixty- four judges, graduate and undergraduate students from different departments, at Michigan State University participated in this test. Each judge was presented with one sample and was asked to examine the color of the skin

Fig.4. Reformed potato product without skin.

Fig.5. Reformed potato product with skin.

Fig.6. Final condition of the coooked reformed potato product.

and the interior, the texture, and flavor for the reformed potato product. Judges were encouraged to provide their comments.

After collecting the data and prior to analysis, the descriptors were assigned the value 1 (extremely poor), 2 (very poor), 3 (poor), 4 (below fair), 5 (fair), 6 (above fair), 7 (good), 8 (very good), 9 (excellent). Figure 7 shows a typical example of the questionnaire which was provided to the judges to give their response in evaluating the product.

III- Statistical analysis:

The standard error of a mean (SEM), the mean, the variance, and the percentage of eac character (color, texture, and flavor) and for overall rating were calculated in order to analyze the sensory evaluation and to get an idea of consumer acceptability.(Gill,1981)

SENSORY ANALYSIS BALLOT

QUALITY GRADING - ONE OR MORE VARIABLES

PRODUCT: SIMULATED BAKED POTATOES DATE: / /

PLEASE RATE THE SAMPLE YOU ARE PRESENTED ACCORDING TO THE FOLLOWING ATTRIBUTES; COLOR, TEXTURE, FLAVOR. PLACE AN X BESIDE THE DISCRIPTOR WHICH BEST EXEMPLIFIES YOUR REACTION TO THE PRODUCT .

	COLOR		TEXTURE	FLAVOR
	SKIN	INTEROR		
EXCELLENT........................				
VERY GOOD........................				
GOOD........................				
ABOVE FAIR........................				
FAIR........................				
BELOW FAIR........................				
POOR........................				
VERY POOR........................				
EXTREMELY POOR........................				

COMMENTS ABOUT OTHER CHARACTERISTICS OF THESE SAMPLES:

Fig.7. Sensory evaluation questionnaire.

RESULTS AND DISCUSSION

I- Manufactured simulated baked potato:

Figure 2 shows a flow diagram for the processing steps of the simulated baked potatoes. Prior to extrusion, the raw potatoes were steamed for 3 minutes in order to gelatinize the starch and thus capture free water. This is important in preventing or controlling " water feedback " during operation of the extruder.

Steaming for 3 minutes was found to be the optimum time required to solve that problem. Steaming for a shorter time was not sufficient and steaming for a longer time produced a mushy texture in the product which was not desirable.

To bind the extruded potato particles together, 7% by weight of non-fat dry milk powder was used as a binding agent, as well as to increase the nutritional value, to improve the color, and to enhance the flavor of the final product.

High temperatures in the extruder, gave the product an undesirable texture while lower temperatures left the product with an unacceptable taste.

Figures 3 and 4 show two photographs of the plastic mold which was used in reforming the extruded potatoes, and the frozen reformed potatoes after being taken out of the mold.

During the deep-frying of the coated potato product two things take place:-

1- Formation of the hard skin during the first minute of deep frying.

2- Developing the desirable color through Maillard reaction during the second two minutes. These changes can be seen in Figs. (5 and 6), which show two photographs of the coated and the coated deep fat-fried potato product and we realize that the coating gave the product a smooth appearance while the deep fat-frying developed and enhanced the appearance.

II- Sensory evaluation of the consumer acceptability:

Processing quality of the simulated baked potatoes was evaluated by a sensory panel in order to examine the acceptability of the product by the consumer.

One of the most important parameters affecting the quality is the flavor. According to Hadziyev 1982, the term "flavor" denotes a complex sensation including odor or aroma, mouth feel, texture, and even appearance.

Figure 10, represents the relationship between the percentage of the judges and their evaluations for the flavor of the simulated potato product. It is evident that most of panelists' evaluations (82%) are between the values excellent to fair.

Color evaluation for the potato skin and interior is given in Fig.8 which shows the relationship between the percentage of the panelists and their evaluation. The majority of the panelists evaluated the samples as excellent to fair (92% and 83%), and only a few of them (8% and 17%) evaluated the skin and the interior respectively as below that. This shows that the color of the new product was accepted by most of the judges.

The relationship between the percentage of the judges and their evaluation of texture is represented in Fig.9. Whereas most of the panelists' evaluations were between the values very good and fair, few of them went above the value very good or below the value fair. However, none of the panelists' evaluations were very poor or extremely poor.

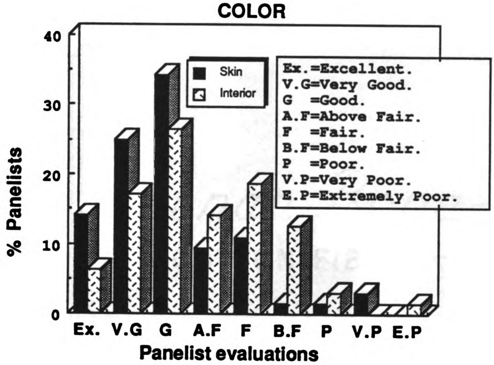

Fig.8. Sensory evaluation for color of reformed potato product.

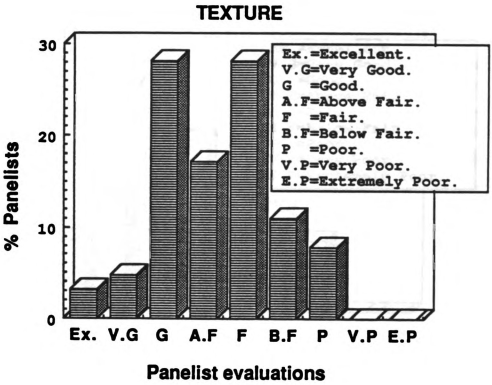

Fig.9. Sensory evaluation for texture of reformed potato product.

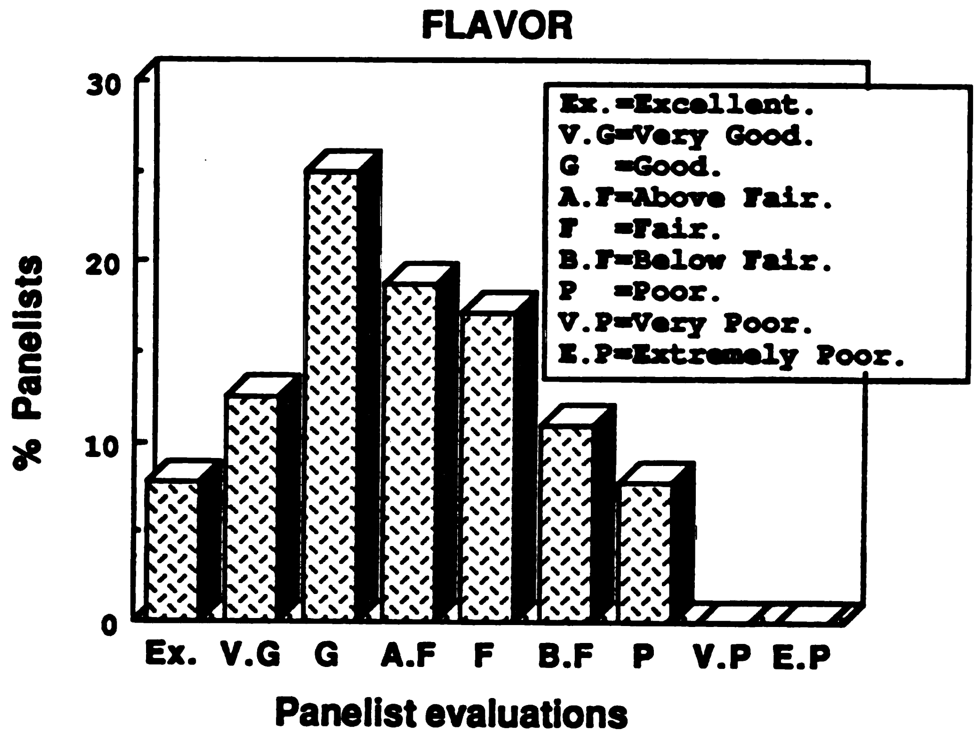

Fig.10. Sensory evaluation for flavor of reformed potato product.

In conclusion from the above figures it is obvious that the majority of the panelists agreed on the acceptability of all the features of the new product. This conclusion is summed up in Fig.11, which represents the overall acceptance of the product.

In the comments from the panelists, those who either disliked the product or graded it poorly, did so because of several reasons:-

1- They were unfamiliar with the baked potatoes due to their place of origin.

2- They do not like plain potatoes and they all commented that if the potato product had been topped with butter, sour cream, or some other topping, their responses would have been much better.

Figures 12, 13, 14, and 15, represent the percentage of the panelists and their responses toward the color (skin, and interior), the texture, the flavor, and overall acceptance. When we devided the panelists' responses into two groups, the first group which includes the responses between the value excellent to the value fair (EX -- F), and the second group which contains the responses between the values below fair to extremely poor (B.F -- E.P), and plotted that against the percentage of the panelists the previous figures were obtained. From those figures we could conclude that over 80% and sometimes over 90% of the panelists their responses were in the first group which is (EX--F), and less than 20% of them their responses were in the second group which is (B.F--E.P), and this is in definite agreement with the other conclusion.

Table 2 (Appendix A), represents the statistical analysis of the sensory evaluation for the remanufactured potato product . The numerical average of the acceptability of each character examined (color, texture, flavor, and

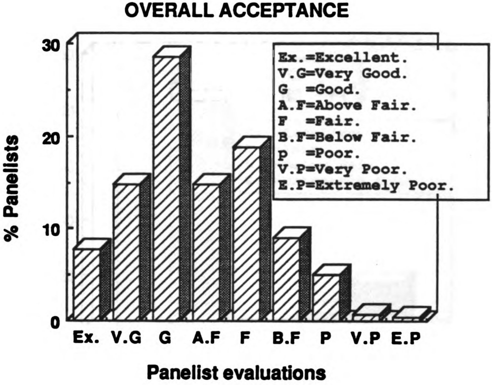

Fig.11. Sensory evaluation for overall acceptance of reformed potato product.

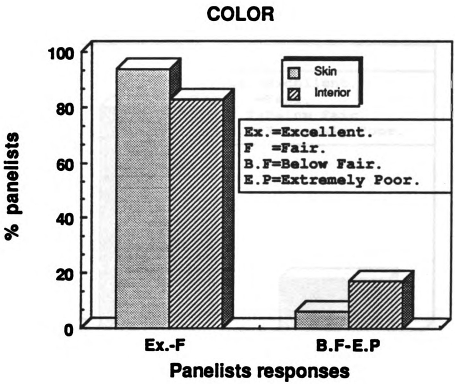

Fig.12. Composite sensory evaluation for color of reformed potatoproduct.

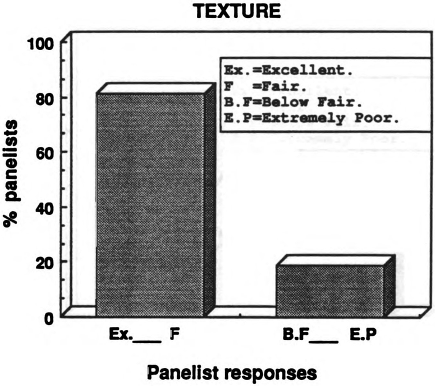

Fig.13. Composite sensory evaluation for texture of reformed potato product.

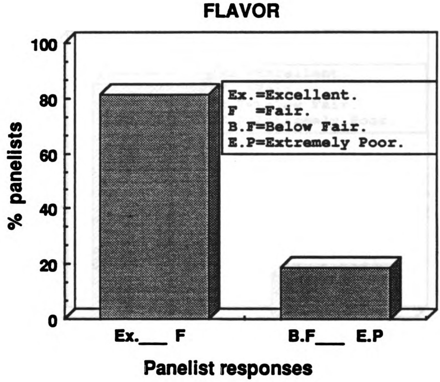

Fig.14. Composite sensory evaluation for flavor of reformed potato product.

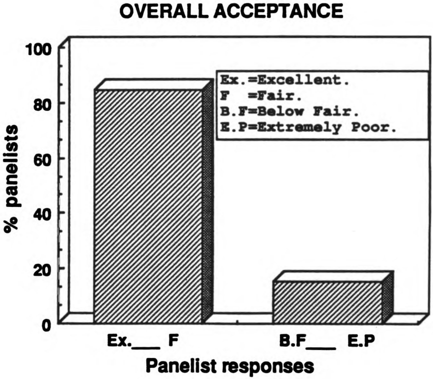

Fig.15. Composite sensory evaluation for overall acceptance of reformed potato product.

overall acceptance) which is shown in the table is based on the scale of 1= extremely poor to 9= excellent .

THE EFFECT OF DIFFERENT PACKAGING MATERIALS AND STORAGE TIME ON PHYSICAL PROPERTIES OF A MANUFACTURED, FROZEN POTATO PRODUCT.

INTRODUCTION

The quality of food products is fragile, because of susceptibility to spoilage, loss of nutrients and changes in color, flavor, odor, and texure. The period between the manufacture of a food product and its retail purchase is defined as" shelf life". The shelf life of a food product varies according to the type of product and its storage conditions.

Storage studies are part of each product development program whether it involves a new product, a product improvement, or simply a change in type or specification of an ingredient. In this study the potato product was packaged in two different moisture barrier materials, and stored in a freezer for a long term in order to determine some of the changes that could take place which might affect the product shelf life. (IFT Expert Panel,1974).

Packaging requirements:-

Plastic materials are used extensively for packaging. In general they provide more protection , and visibility of the product than some other materials like paper. The availability of these materials in different forms and the great improvement in their resistance to moisture, water vapor transmission, and grease, and easy closure has led to widespread use of plastics for foods (Paine, 1983).

Polyethylene film is one of the largest volume commercial polymeric materials and its structural characterization is of great interest (Mathlouthi, 1986). It is more strongly hydrophobic than many other organic films, so water vapor penetrates it to a limited degree. This particular property, along with its high rate of gas permeability, are of considerable value in the packaging of items which require a low moisture loss, while maintaining the ability to transmit significant amounts of oxygen or carbon dioxide (Saad, 1989).

The principal film materials used for food bags are low and high density polyethylene. Low density polyethylene (LDPE) is the more widely used of these two because of its flexibility and cost. It can be extruded into film, blown into bottles, injection molded into closures and dispensers of all sorts, extruded as a coating on paper, aluminium foil or cellulose film, and made into large tanks and other containers by rotational casting (Paine, 1983).

The permeation of water vapor through a packaging material has a great deal of influence on the preservation of food quality. Mathlouthi, (1986) and Paine (1983) reported that a good frozen food package must withstand low temperatures, provide a barrier to transmission of water vapor, must be water-resistant, non-toxic and impart no odor or flavor to the food.

Ben-Yehoshua (1979) reported that wrapping lemon in high density polyethylene film (HDPE) reduced weight loss and slowed softening. Also, he found that seal-packaging (shrink wrapping) of fruit in 0.01 mm HDPE film markedly reduced the loss of weight in oranges stored under normal conditions for shipping or storing.

Risse et al. (1984) and Miller and Risse (1986) found that by using a combination of shrink-wrapping, irradiation and refrigeration, deterioration of produce was slowed considerably.

Deak et al. (1987) studied extending the shelf life of fresh sweet corn by shrink-wrapping and refrigeration. It was shown that wrapping essentially eliminated moisture loss and resulted in extended shelf life.

Anzueto and Rizvi (1985) and Ben-Yehoshua (1985) found that the shrink-wrapping of fruits and vegetables in plastic films appear to be simple and inexpensive alternatives. Also, they found that shrink-wrapped produce had an extended shelf life of several weeks, even at ambient temperature.

The effect of moisture loss during storage:

Texture and color are two important criteria used in the U.S. grading standards for frozen French fries (Talburt and Smith, 1975). There are many factors which are related to the changes in texture and color. One of these factors is the moisture loss during storage of the product. Dehydration can be caused by moisture vapor, produced by variations of temperature created within the package, escaping through the walls or ineffective seals of the package. This moisture loss dehydrates the surface of the frozen food which causes freezer burn. The dehydrated surface layer can be very thin, but may affect the appearance and ultimate saleability of the product (Paine, 1983).

Sych et al.(1987) studied the effect of initial moisture content and storage relative humidity on textural changes of layer cakes during storage, and found that there was an inverse relationship between the initial moisture content and the cakes' firmness. Also, they reported that the loss of the product moisture content throughout the storage period can be minimized by increasing the storage relative humidity.

Potato color:

Color and discoloration of foods are important quality attributes in marketing. Color is often used to determine the ripeness of fruit, but often is used to give some idea about the changes which are taking place during processing or long term storage (Pomeranz, 1987).

Color is a very readily discernible attribute for estimating quality of potato products. The optimum color for steamed, boiled, baked, or mashed potatoes is creamy white. For fried potato products, a highly uniform golden crust is considered optimum. Off-color is usually associated with after-cooking darkening of fresh tubers or with the undesirable darkening from the non-enzymatic browning reaction that may occur during frying or dehydration. For optimum color, low reducing sugar content is desirable, especially for chips and French fries (Zaehringer et al., 1967).

Johnson (1957) and Lyman (1961) found that potato chips from tubers of high specific gravity were lighter in color than chips from tubers of low specific gravity. Lujan and Smith, (1964) found a positive relationship between specific gravity and after- cooking darkening of potatoes.

Texture Profile Analysis:

Texture, appearance, and flavor are three major components of food acceptability (Bourne, 1978) which may be susceptible to deterioration during long-term storage. The degree of deterioration and its influence on consumer acceptability determine the shelf life of a product .

Texture quality is considered to be one of the most important single factors in determining suitability of potatoes for processing and it is also a very good indicator of the deterioration taking place during storage of the product.

The Texture Profile Analysis (TPA) technique is a very important tool in terms of giving a good understanding of the textural properties of foods. It can be used to follow changes in different textural parameters as a result of changes taking place in formulation and processing as well as during storage of foods (Bourne, 1978). Schmidt and Ahmed (1971) used the TPA method to study the effect of peeling methods on textural properties of cooked potatoes.

Although the texture of cooked potatoes is usually evaluated by sensory methods, Zaehringer et al. (1962) reported that in certain types of research it is necessary to evaluate the texture of a large number of samples, a situation that raises certain problems. If the samples are scored at a single sitting, the judges may experience sensory fatigue. On the other hand, if the samples are judged over an extended period, interpretation of the descriptive terms may fluctuate with time and with the ability of the judges to recall. Therefore, instrumental methods are used to evaluate textural properties in order to obtain information related to the manner in which the consumer identifies these properties (Shama, 1973).

The Instron Universal Testing Machine can be meaningfully employed to evaluate the textural properties of food (Shama, 1973). The first attempt to apply the Instron Universal Machine to objective TPA was done by Bourne (1968). He determined TPA parameters of hardness, brittleness, cohesiveness, elasticity, chewiness and gumminess by interpreting first and second bite compression curves according to the procedure outlined by Friedman et al. (1963).

Adhesiveness is defined as the work necessary to overcome the attractive forces between the surface of the food and the surface of other materials with which the food comes in contact such as the tongue, the teeth, etc. (Sherman, 1969). It is calculated from the negative force area for the first bite in the TPA curve.

Cohesiveness is defined as the ratio of the positive force area during the second compression to that during the first compression, and it represents the degree to which the sample deforms before it ruptures (Bourne, 1978, Montejano et al., 1985).

Hardness is defined as the peak force during the first compression cycle " first bite", whereas gumminess is defined as the energy required to disintegrate a semisolid food product to a state ready for swallowing (Sherman, 1969) and calculated as the product of hardness and cohesiveness.

Sherman (1969) reported that the relative importance of cohesion and adhesion depends on their magnitude. When adhesion force is larger than the cohesion force, part of the food will adhere to the teeth. On the other hand, the particles of the food will not be retained on the teeth when the cohesion forces are larger than the adhesion forces.

Following the pioneering work of Bourne et al. (1966) and Bourne (1968) the Instron Universal Testing Machine has been widely used in evaluation of textural properties of food (Shama, 1973). Henry et al., (1971) used the Instron to measure and to develop the analysis of the adhesiveness for semi- solid foods.

MATERIAL AND METHODS.

I- Preparation of the potato product for freezing storage:

The potato product was divided into three groups. One group was packaged in low density polyethylene bags, the second group was packaged in laminated retortable pouches, while the last group was left without packaging as a control. All of the three groups were stored under freezing condition for seven months.

II- Packaging materials:

Two different packaging materials were used in this study. The first one was commercial low density polyethylene (LDPE) 2 mil bags from Packaging Concepts and Design, a division of Bader Bag Co. Madison Heights, Michigan. The second packaging material was 6 mil Laminated retortable pouches PP / Al . foil / PET (Polypropylene / Aluminum foil / Polyethyleneterphthalate) from American Can Co. (Material Number K 125 44-050). The materials were cut to form small pouches with dimensions of 6" X 8" and heat-sealed on three sides by using a variable speed roller sealer (manufactured by the ARO CORPORATION, Model # PN F 100-1000) at a temperature of 400^{o}F and speed 20%. The potato products were packaged individually, then the bags were sealed in such a way as to minimize the space between product and package to avoid the problem of freezer burn, which could result from the loss of moisture from the product during storage.

III- Determination of Water Vapor Transmission Rate (WVT):

The water vapor transmission rate (WVT) of the test packages at ambient condition and in the freezer was determined as described in ASTM.E-96 method as follows:-

Ten bags of each material were used in this study. About 35 g. of desiccant was put in each bag, heat-sealed and weighed. Five bags of each material were stored at ambient condition (in the lab.), while the rest of the bags were stored in the freezer. The storage period was 14 days. After that the bags were weighed again (every two days) to calculate the amount of water vapor absorbed by the desicant.

The following equation was used to calculate the water vapor transmission rate:-

$$WVT = W/(A \times t)$$

where:-

W= Weight gain or loss in g.,

A= Exposed area of the package material (total area of the two sides of bag) in m^2.,

t = Time, during which gain or loss was observed in hours.,

WVT= Rate of water vapor transmission in g / m^2. day.

IV- Determination of moisture content:

To monitor the extent of potato product dehydration throughout long-term storage, moisture determinations (wet basis) for the skin and the interior were carried out in triplicate, and performed initially and on a monthly basis.

About 5.00 g of the potato product which was stored frozen in LDPE bags, in retortable pouches, and without package (control) were dried overnight at 80°C in a vacuum oven (25 inch Hg).

V- Determination of color:

The color of the potato product crumb was determined using a Color Difference Meter, Model 25 (Hunter Associated Lab., Inc., Fairfax, Virginia). Two samples of each treatment (LDPE, R.P, and control) were taken out of the freezer, and the package removed. The samples were microwaved for 2.5 min. at full power, then were held for 5 min. at room temperature.

After removing the crust of the samples of each treatment they were placed in a half-filled glass cell (diameter 10 cm, height 5 cm) on the aperture of an inverted Hunter photoreceptor unit. The sample and glass cell were then covered with a black cylinder to reduce stray light. The instrument was standardized prior to analysis, using a standard white tile ($L= 92.35$, $a_L= -1.2$, $b_L= 0.5$).

VI- Texture analysis:

Texture Profile Analysis (TPA) was used to evaluate force compression curves obtained on potato samples with the Instron Universal Testing Machine (Model 4202). A 5.00 cm diameter plunger, attached to the Instron, compressed the potato samples twice in sequence. The Instron was operated with a crosshead speed of 10 cm/min., chart speed of 38 cm/min., distance travel of the plunger 1.5 cm in the sample, and a full scale load of 20.00 N.

These operating conditions were used to determine the hardness or firmness, cohesiveness, adhesiveness, and gumminess of the potato samples during storage .

Sample preparation:

Two samples of each packaging and control treatment were used to determine the TPA initially and five times during the storage period (2nd, 4th, 5th, 6th, and 7th month of storage). The potato samples were microwaved for 2.5 min., then held at room temperature for 5 min. before shaping into cubes of 8 cm^3 volume. The textural values reported are averages of 8 measurements.

A generalized Instron TPA curve is shown in Fig.16. The curve shows sharp peaks at the end of each compression due to the fact that the compression speed of the Instron is constant and there is abrupt reversal of direction at the end of each line. As shown in the figure , the height of the first compression measured the resistance of the potato product crumb to the penetrating plunger and represented the hardness of the potato crumb.
The negative force area for the first compression (A_3) is known as the adhesiveness. Ahesiveness is measured in instrument units of the negative peak obtained as the plunger withdraws from the sample in the first cycle. This area is said to represente the work necessary to pull the compression plunger away from the sample.
The ratio of the positive force areas (A_2/A_1) under the first and the second peaks represents the cohesiveness of the potato interior. These areas are said to represent the work done in each cycle and the ratio is said to be a direct function of the work done in overcoming the internal bonds of the material. Gumminess was calculated from the product of hardness and cohesiveness.

VII- Statistical analysis:

Two factor analysis of variance (ANOVA) was carried out on the observations from each variable measured (% moisture of skin and interior, color changes, and Texture Profile Analysis). The factors included the three

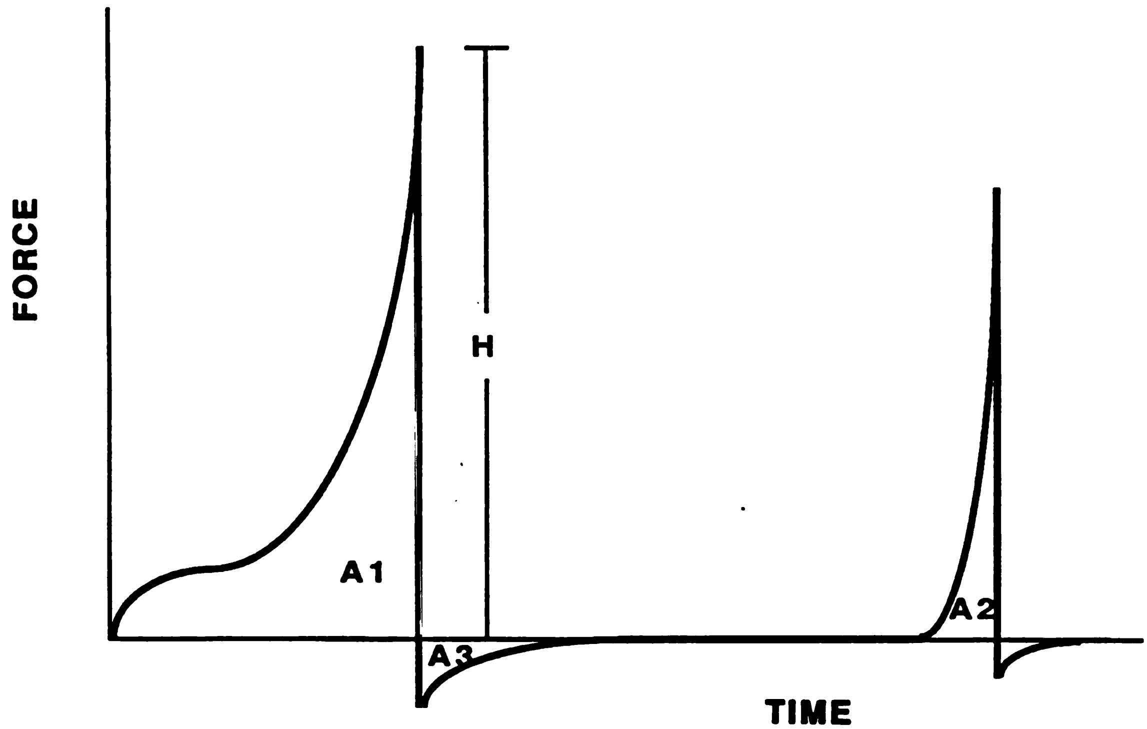

Fig.16. Typical first and second bite compression curves for Instron Universal Machine.

H = Hardness or Firmness. A_2/A_1 = Cohesiveness.
A_3 = Adhesiveness.

treatments (packaged in LDPE, packaged in R.P, and non-packaged) , and the storage periods. This permitted the calculation of the variance due to treatment effects, storage effects, their interactions,
and the estimation of experimental error. Comparison of treatment differences was done by Tukey's Honestly Significant Difference test (HSD). The correlation coefficients (CORR) procedure was used to establish the relationship between the variables obtained by the three treatments.

RESULTS AND DISCUSSION

Packaging of produce in polymeric films is a common technique designed to prevent moisture loss, to protect against mechanical damage, and to provide better appearance. Proper selection of packaging films can favorably alter any undesirable changes taking place during long-term storage, resulting in an extended shelf life and improved quality (Heing and Gilbert, 1975).

Table 3 shows the water vapor transmission rate (WVT) values for the two packaging materials, low density polyethylene (LDPE), and laminated retortable pouch (R.P), under two different conditions (ambient and freezing condition). The laminated film appeared to allow less moisture to permeate than the LDPE film under both conditions. Also, the differences in the WVT values were affected not only by the packaging materials or the thickness of the films, but they were affected also by the conditions during the experiment (temperature and relative humidity).

As expected, packaged potatoes which were held at freezing conditions for seven months tended to show slower rates of moisture content loss for skin and interior than their nonpackaged counterparts (Figs. 17 and 18).

Although the percentage of moisture content loss of both packaged and nonpackaged potato product during the storage was observed, it was obvious that the trend of moisture loss in the packaged product was negligible compared to that in the control (unpackaged).

The percentage loss of the moisture content in the skin and the interior for the nonpackaged potatoes was 22% and 8% respectively. However, for the potatoes packaged in LDPE and R.P and stored at the same conditions for

Table -3. Water vapor transmission rate (WVT) of two packaging materials low density polyethylene (LDPE) and retortable pouch (R.P) at two different conditions.

Packaging material	Conditions	WVT g/m^2. day
LDPE	Ambient	1.430
	Freezer	0.055
R.P	Ambient	0.042
	Freezer	0.022

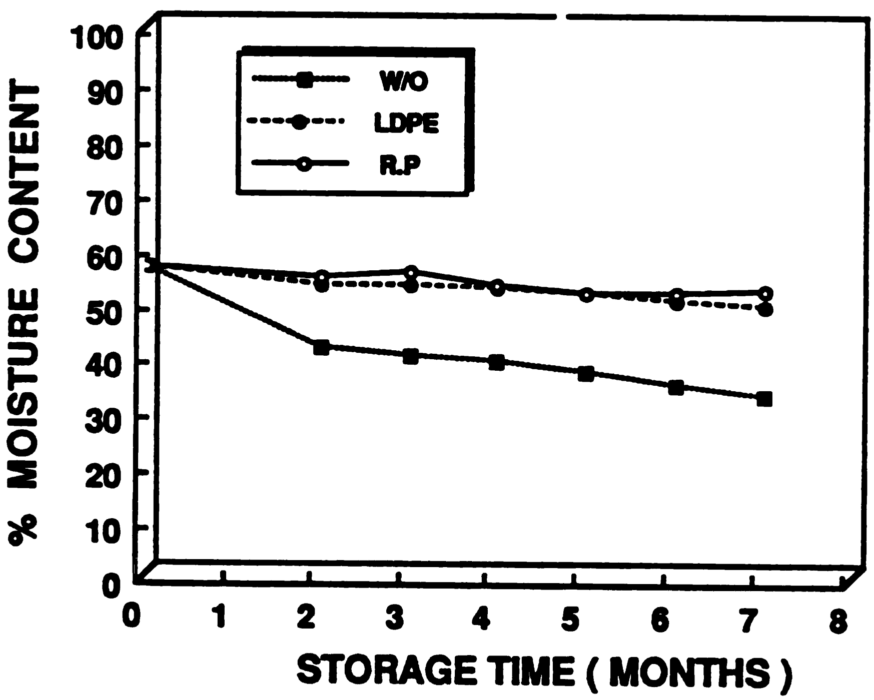

Fig.17. Change of the skin moisture content for the simulated baked potato product in different packaging material during frozen storage.

W/O = Unpackaged.
LDPE = Packaged in low density polyethylene.
R.P = Packaged in laminated retortable pouch.

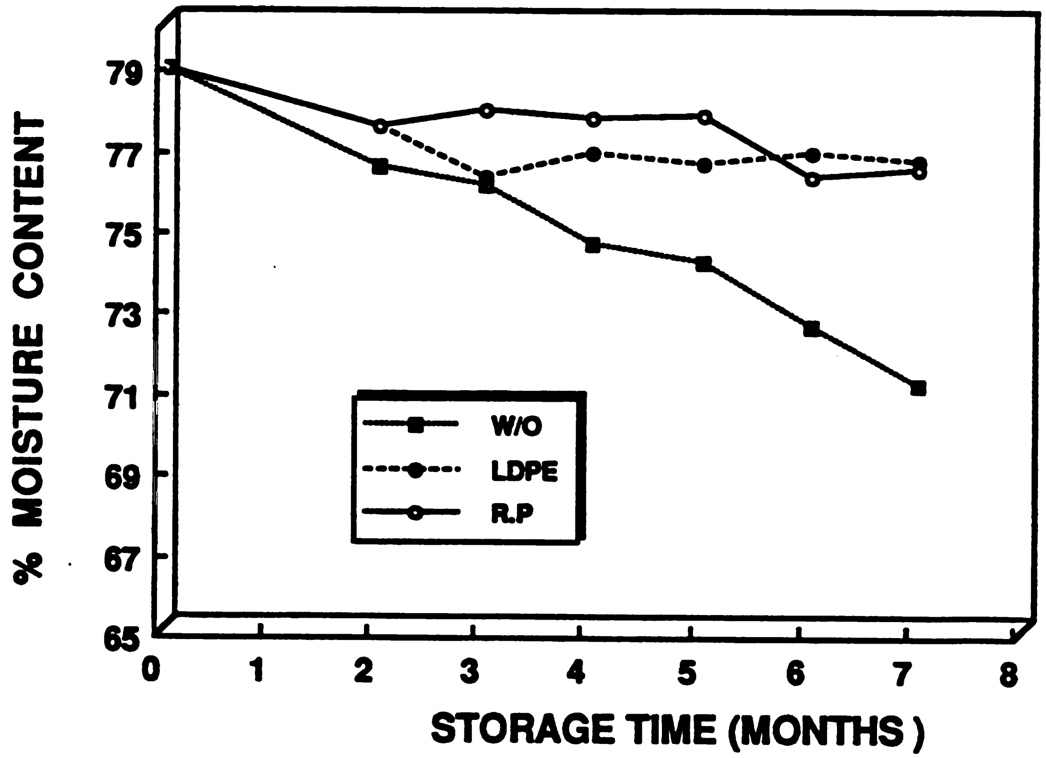

Fig.18. Change of the Interior moisture content for the simulated baked potato product in different packaging material during frozen storage.

W/O = Unpackaged.
LDPE = Packaged in low density polyethylene.
R.P = Packaged in laminated retortable pouch.

seven months the moisture loss in the skin was 7% and 4% and for the interior was 2% for both packaging materials and this idicates that the individual film packaging reduced the moisture loss. This may be explained by the effect of packaging materials which retarded the moisture vapor permeation from the inside to the outside atmosphere.

Table 6 (Appendix C) shows that the differences between the changes in the moisture content in the interior for the potato product packaged in two different packaging materials were not significant, and this is in agreement with the data in table 14 (Appendix D) which indicates that there are no significant differences ($p=0.05$) between the two packaged treatments.

A slight decline in color (L-value) was observed for individually packaged and nonpackaged potato products under all storage periods studied. Figure 19 shows that nonpackaged products had a higher level of decline than the packaged products. However, the color (b-value) of both the packaged and nonpackaged potato product stored under the same conditions and the same period did not appear to be significantly affected (Fig. 20).

Loss of moisture content from the potato product during the storage period was also manifested in the increase of the firmness value. This behavior can be attributed to the dehydration effect due to moisture loss during the storage period. The results of the correlation coefficient indicate that the trend of firmness agrees with the trend of moisture loss in all treatments because when the food material loses water, its particles stick together and this will cause resistance to the penetration of the instron plunger, which translates as an increase in firmness value.

Firmness is affected by the packaging treatment, and storage time. However, there was almost no difference in this value for the packaged potato product for the first five months of storage. The differences started to increase

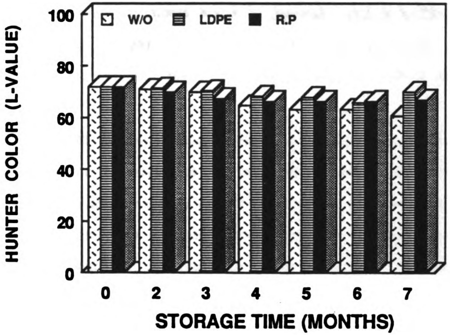

Fig.19. Change of the color L-value for the simulated baked potato product in different packaging material during frozen storage.

W/O = Unpackaged.
LDPE = Packaged in low density polyethylene.
R.P = Packaged in laminated retortable pouch.

after that, due to differences in the water vapor transmission rate between the LDPE and the R.P. Potato products packaged in LDPE bags were firmer than the product packaged in R.P.

Generally speaking, the firmness value was higher for the unpackaged potato product and lower for the packaged product. This is in agreement with the trend of moisture loss (Figs. 21 and 35-37 Appendix B).

Changes in the cohesiveness value of the potato product followed the same pattern in all treatments studied (packaged and nonpackaged) during the storage period (Fig.22). The cohesiveness value gradually increased and reached the maximum at the fifth month of storage then it declined slightly again.

Figure 23 represents the relationship between the adhession value and storage time for the packaged and nonpackaged potato product. The trend of changes in this relationship is similar to the trend of changes in cohesion. The figure shows that the adhesion value gradually increased and reached its maximum between fifth and the sixth month of storage then started to decline. At all storage times the adhesiveness value of the nonpackaged product was lower than the value of the packaged one.

Based on TPA data, (Fig.24 and Figs.34-44 Appendix B) the unpackaged potato product (control) was the gummiest . However, there were no significant differences in the cohesiveness values for the three treatments at any time of storage (Fig.38 Appendix B).

The results obtained showed that the nonpackaged potato product had the higher gumminess values than the packaged potatoes, may have been because of the higher firmness values which were used in calculating gumminess.

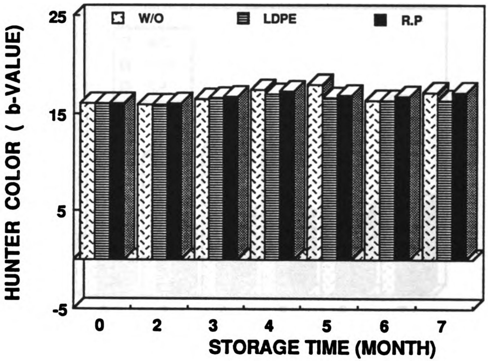

Fig.20. Change of the color b-value for the simulated baked potato product in different packaging material during frozen storage.

W/O = Unpackaged.
LDPE = Packaged in low density polyethylene.
R.P = Packaged in laminated retortable pouch.

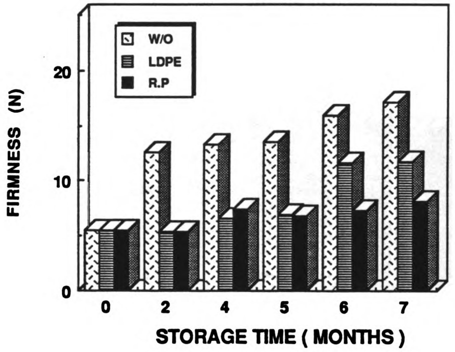

Fig.21. Change of the firmness for the simulated baked potato product in different packaging material during frozen storage.

W/O = Unpackaged.
LDPE = Packaged in low density polyethylene.
R.P = Packaged in laminated retortable pouch.

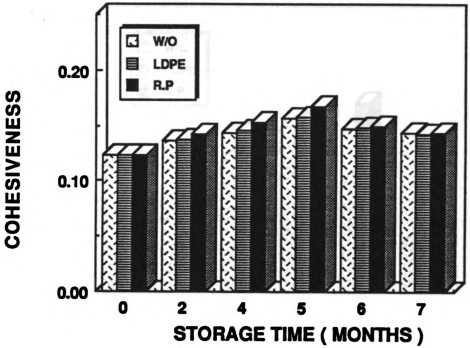

Fig.22. Change of the cohesiveness for the simulated baked potato product in different packaging material during frozen storage.

W/O = Unpackaged.
LDPE = Packaged in low density polyethylene.
R.P = Packaged in laminated retortable pouch.

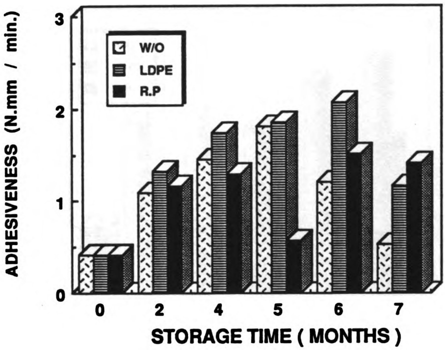

Fig.23. Change of the adhesiveness for the simulated baked potato product in different packaging material during frozen storage.

W/O = Unpackaged.
LDPE = Packaged in low density polyethylene.
R.P = Packaged in laminated retortable pouch.

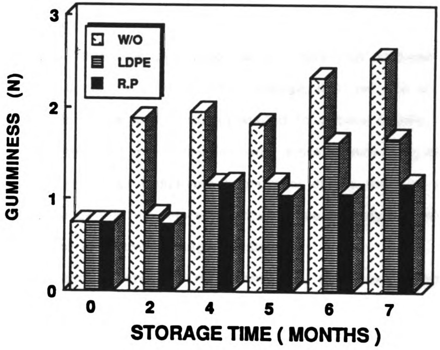

Fig.24.Change of the gumminess for the simulated baked potato product in different packaging material during frozen storage.

W/O = Unpackaged.
LDPE = Packaged in low density polyethylene.
R.P = Packaged in laminated retortable pouch.

Interaction of treatments and storage time imply that the rate of loss of moisture (Fig. 17) and the rate of increase of firmness and gumminess (Figs. 21 and 24) are not the same for the three groups (packaged and unpackaged). Obviously, the rate of loss of moisture and the rate of increase in firmness and gumminess is much greater in the unpackaged treatment, and the main effects of treatments and storage times are irrelevant. The rate of changes of moisture, firmness and gumminess for the unpackaged treatment are greater than the packaged treatments from the second month of storage to the end of the storage period.

Figure 19 shows that there is no interaction between treatments and storage time up to the third month of storage, then the rate of change of color L-value for the unpackaged product started to decline rapidly. However, in the relationship between color b-value and storage time (Fig.20) the trend of changes for the three treatments is parrallel during the first three months of storage and after that the rate of change for the unpackaged treatment began to differ from the other two packaged treatments.

Correlations between TPA parameters, moisture content for skin and interior, and color values (L,b) are summarized in Table 4.
Firmness has a positive correlation with gumminess, whereas the color b-value has a positive correlation to all the TPA parameters. The moisture content (skin and interior) also had a positive correlation with adhesiveness, cohesiveness, and color L-value. However, the color L-value had a negative correlation with the other parameters except the adhesiveness. The correlation between the moisture content of skin and interior is also positive. Table 5-12 (Appendix C) show the analysis of variance (ANOVA) of the variables studied for the simulated baked potato product (packaged and nonpackaged). These tables show the treatment effects, storage effects and the interaction between

Table -4. Correlation coefficients and confident intervals for the different variables changes during the storage period.

	Moisture of Skin.	Moisture Interior.	Color "L" Value.	Color "b" Value.	Firmness.	Cohesiveness.	Adhesiveness.	Gumminess.
Gumminess.	-0.87 (-0.93 : -0.74)#	-0.82 (-0.90 : -0.63)#	-0.68 (-0.82 : -0.41)#	+0.24 (-0.12 : +0.56)#	+0.98 (+0.96 : +0.99)#	-0.09 (-0.43 : +0.28)#	-0.21 (-0.53 : +0.18)#	
Adhesiveness.	+0.22 (-0.16 : +0.53)#	+0.22 (-0.16 : +0.53)#	+0.13 (-0.22 : +0.48)#	+0.07 (-0.41 : +0.30)#	-0.20 (-0.52 : +0.19)#	-0.02 (-0.38 : +0.34)#		
Cohesiveness.	+0.19 (-0.17 : +0.51)#	+0.14 (-0.23 : +0.48)#	-0.25 (-0.55 : +0.13)#	+0.28 (-0.10 : +0.57)#	-0.18 (-0.51 : +0.18)#			
Firmness.	-0.89 (-0.95 : -0.78)#	-0.83 (-0.92 : -0.68)#	-0.66 (-0.81 : -0.38)#	+0.22 (-0.16 : +0.54)#				
Color "b" Value.	-0.26 (-0.55 : +0.10)#	-0.27 (-0.55 : +0.12)#	-0.60 (-0.77 : -0.32)#					
Color "L" Value.	+0.58 (+0.32 : +0.78)#	+0.71 (+0.47 : +0.83)#						
Moisture Interior.	+0.85 (+0.70 : +0.93)#							
Moisture of Skin.								

95 % Confident Intervals.

treatment and storage. Also, they show significance of these effects, as well as level of significance. However, Tables 13-19 (Appendix D) represent the changes of the variables studied (moisture, color, and TPA values) for the packaged and the nonpackaged potato product within the time of storage. These tables show the mean for each treatment at each time of storage and the standard error of the mean SEM, as well as the level of significance.

Generally speaking, the quality of potato product which was packaged in LDPE bags did not appear to be recognizably different from the quality of potatoes which were packaged in laminated retortable pouches, but significant differences were seen between the packaged and unpackaged product.

The bottom line is that the physical deterioration of the manufactured potato product in frozen storage was delayed by individual packaging in moisture resistant polymeric films (2 mil LDPE, and 6 mil laminated retortable pouch). The nonpackaged potato product held under the same storage conditions, obviously lost significant amounts of moisture especially from the skin, and gained higher hardness values compared to the packaged ones.

The differences in properties between the potato product packaged in LDPE and the one packaged in the laminated retortable pouch were not significant ($p=0.05$). Therefore, the use of 2 mil low density polyethylene as a packaging material for the manufactured baked potato product is very suitable from the economical point of view, as well as, the standpoint of quality maintenance.

SUMMARY AND CONCLUSION

In any given year, a portion of the potato crop will be graded into small, extra large or off-grade classes. Some of these tubers may find acceptance in certain types of processed products but this is usually minimal. Therefore, it is imperative that new processed products be developed which can utilize that portion of the potato crop which is not suited for use in presently established processed products.

It is feasible to use the twin screw extruder to manufacture the simulated baked potato product. Prior to extruding, steaming of the potatoes, and adding binding agent were done in order to prevent any problem during extruder operation and to bind the extruded potato particles together. Plastic molds were used in reforming the extruded potatoes, then simulated skin was developed for the final frozen product.

Sensory analyses were performed on the product to determine consumer acceptability. Discriminatory and preference tests indicated that a majority of panelists (over 80% and sometimes over 90%) rated the product as excellent to fair for color, texture, flavor, and overall acceptance.

Stability of the product during frozen storage for seven months in two different packaging materials (low density polyethylene and laminated retortable pouch) was studied. The data showed that physical deterioration, such as moisture content for the skin, and the interior, color, texture profile analysis (TPA) of the manufactured potato product in frozen storage, was delayed by individual packaging in moisture resistant polymeric films. The correlation between TPA and the color b-value was positive, as was the moisture content, adhesiveness, cohesiveness and the color L-value. However, the color L-value had a negative correlation with the other parameters except adhesiveness.

The differences in properties (moisture content, color, TPA values) between the potato product packaged in LDPE and the one packaged in the laminated retortable pouch were not significant (p=0.05).

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APPENDIX - A

Table -2. Statistical summary of the sensory evaluation .

	COLOR OF SKIN	COLOR OF INTERIOR	TEXTURE	FLAVOR	OVERALL ACCEPTANCE
MEAN#	6.95	6.19	5.73	6.11	6.25
VAR.	2.55	2.89	2.14	2.80	2.76
SEM	0.20	0.21	0.18	0.21	0.10
mean±SEM	6.95±0.2	6.19±0.21	5.73±0.18	6.11±0.21	6.25±0.1

Mean of 64 individual.
Each variable is rated from 1-9.

APPENDIX - B

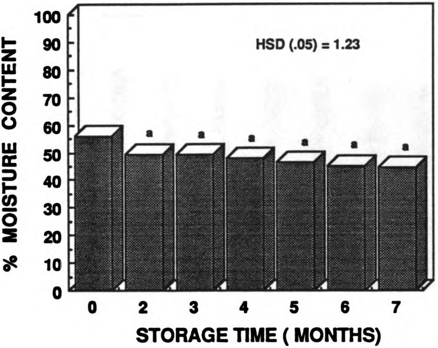

Fig.25. Change of the skin moisture content for the simulated baked potato product during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

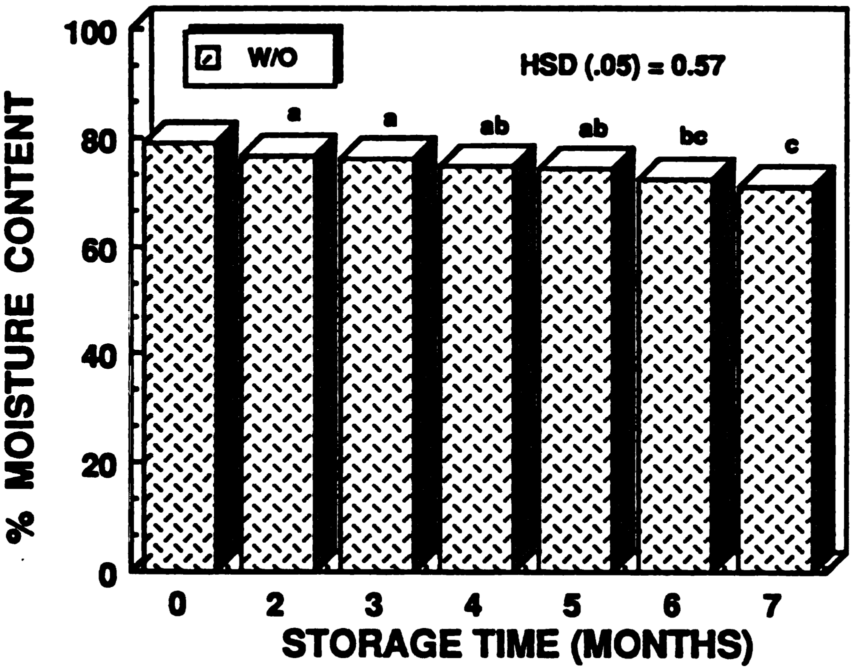

Fig.26. Change of the internal moisture content for the unpackaged simulated baked potato product during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

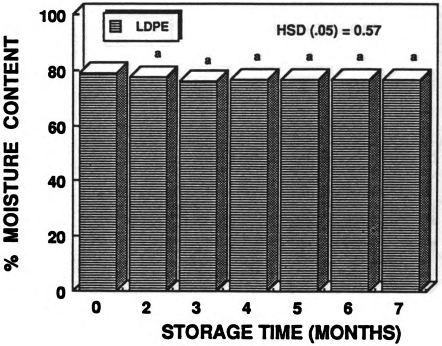

Fig.27. Change of the internal moisture content for the simulated baked potato product in low density polyethylene package during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

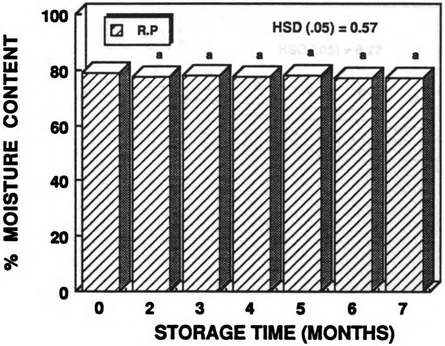

Fig.28. Change of the internal moisture content for the simulated baked potato product in retortable pouch during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

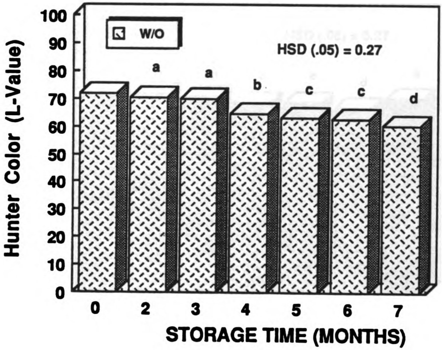

Fig.29. Change of color L-value for the unpackaged simulated baked potato product during frozen storage.

Columns which has the same letter are not significantly different @ $\alpha = 0.05$

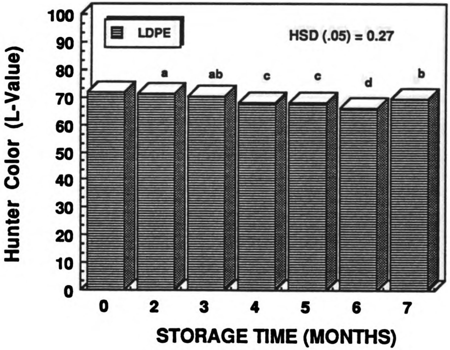

Fig.30. Change of color L-value for the simulated baked potato product in low density polyethylene package during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

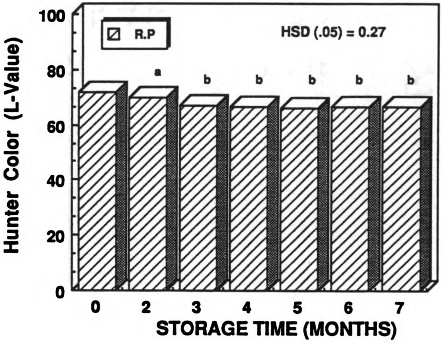

Fig.31. Change of color L-value for the simulated baked potato product in retortable pouch during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

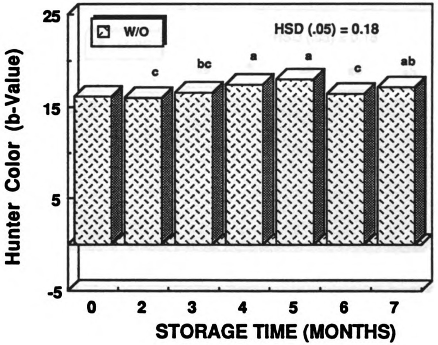

Fig.32. Change of color b-value for the unpackaged simulated baked potato product during frozen storage.

Columns which has the same letter are not significantly different @ $\alpha = 0.05$

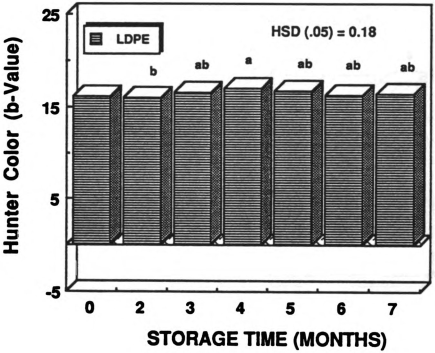

Fig.33. Change of color b-value for the simulated baked potato product in low density polyethylene package during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

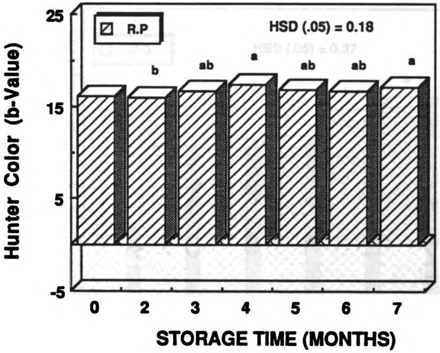

Fig.34. Change of color b-value for the simulated baked potato product in retortable pouch during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

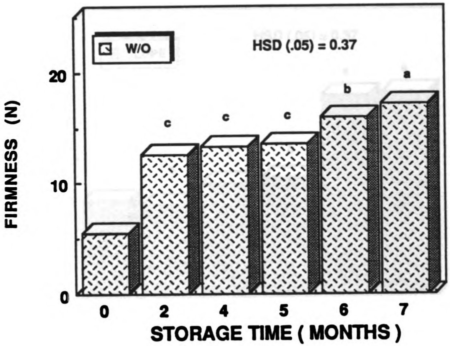

Fig.35. Change of firmness for the unpackaged simulated baked potato product during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

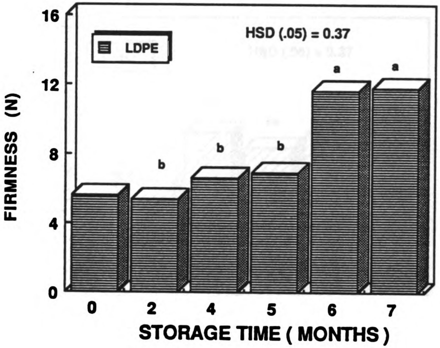

Fig.36. Change of firmness for the simulated baked potato product in low density polyethylene package during frozen storage.

Columns which has the same letter are not significantly different @ $\alpha = 0.05$

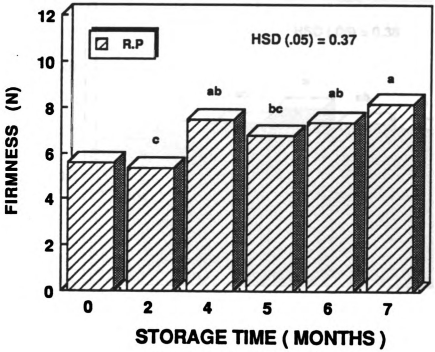

Fig.37. Change of firmness for the simulated baked potato product in retortable pouch during frozen storage.

Columns which has the same letter are not significantly different @ $\alpha = 0.05$

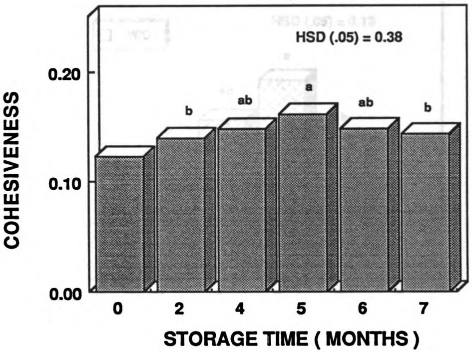

Fig.38. Change of cohesiveness for the simulated baked potato product during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

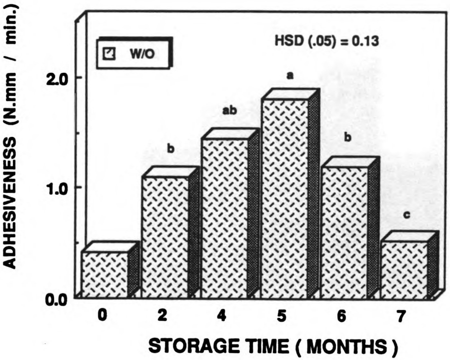

Fig.39. Change of the adhesiveness for the unpackaged simulated baked potato product during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

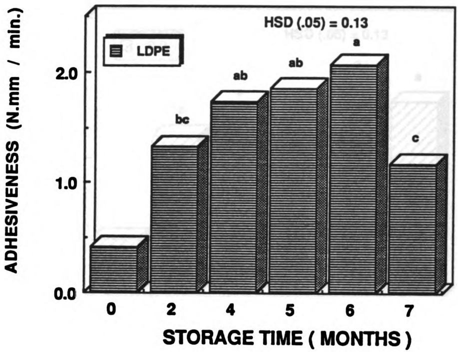

Fig.40. Change of the adhesiveness for the simulated baked potato product in low density polyethylene package during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

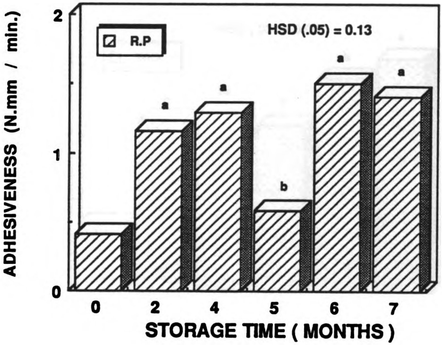

Fig.41. Change of the adhesiveness for the simulated baked potato product in retortable pouch during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

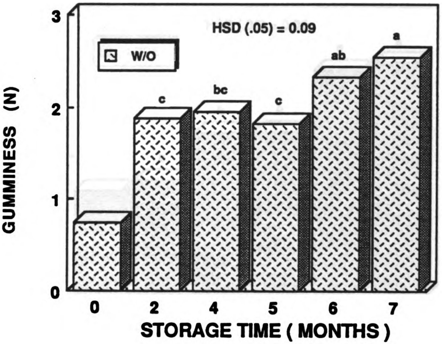

Fig.42. Change of the gumminess for the unpackaged simulated baked potato product during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

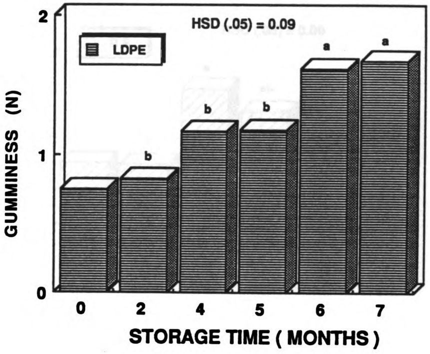

Fig.43. Change of the gumminess for the simulated baked potato product in low density polyethylene package during frozen storage.

Columns which has the same letter are not significantly different @ $\alpha = 0.05$

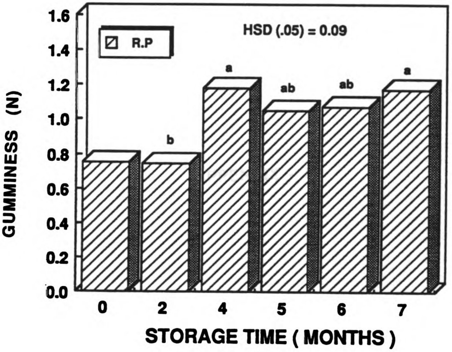

Fig.44. Change of the gumminess for the simulated baked potato product in retortable pouch during frozen storage.

Columns which has the same letter are not significantly different @ α = 0.05

APPENDIX - C

Table -5. Analysis of variance for moisture of skin in simulated baked potatoproduct stored unpackaged, in low density polyethylene, or laminated retortable pouches.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
Treat.(Pkgs.)	2	1737.40	868.70	94.98**	0.00
Storage	5	126.40	25.28	2.76**	0.05
Interaction	10	31.85	3.19	0.35	
Error	18	164.63	9.15		

** Significant @ p=0.01 level

Table -6. Analysis of variance for moisture of interior in simulated baked potato product stored unpackaged, in low density polyethylene, or laminated retortable pouches.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
Treat. (PKGS.)	2	70.47	35.23	54.29**	0.00
Storage	5	23.23	4.65	7.16**	0.00
Interaction	10	25.14	2.51	3.87**	0.006
Error	18	11.68	0.65		

** Significant @ p= 0.01 level.

Table -7. Analysis of variance for color L value in simulated baked potato product stored unpackaged, in low density polyethylene, or laminated retortable pouches.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
Treat. (PKGS.)	2	79.71	39.85	273.24**	0.00
Storage	5	155.08	31.02	212.64**	0.00
Interaction	10	70.46	7.05	48.31**	0.00
Error	18	2.63	0.15		

** significant @ p= 0.01 level.

Table -8. Analysis of variance for color b value in simulated baked potato product stored unpackaged, in low density polyethylene, or laminated retortable pouches.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
Treat. (PKGS.)	2	1.24	0.62	9.88**	0.001
Storage	5	6.51	1.30	20.85**	0.000
Interaction	10	1.98	0.20	3.17*	0.016
Error	18	1.13	0.06		

* Significant @ p= 0.05 level.
** Significant @ p= 0.01 level.

Table -9. Analysis of variance for Firmness in simulated baked potato product stored unpackaged, in low density polyethylene, or laminated retortable pouches.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
Treat.(PKGS.)	2	352.47	176.24	649.59**	0.00
Storage	4	85.08	21.27	78.40**	0.00
Interaction	8	26.15	3.27	12.05**	0.00
Error	15	4.07	0.27		

** Significant @ p= 0.01 level.

Table -10. Analysis of variance for Adhesiveness in simulated baked potato product stored unpackaged, in low density polyethylene, or laminated retortable pouches.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
Treat.(PKGS.)	2	1.22	0.61	18.72**	0.00
Storage	4	1.25	0.31	9.59**	0.00
Interaction	8	2.72	0.34	10.41**	0.00
Error	15	0.49	0.03		

** Significant @ p= 0.01 level.

Table -11. Analysis of variance for Cohesiveness in simulated baked potato product stored unpackaged, in low density polyethylene, or laminated retortable pouches.

Source	Degrees of Freedom	Sum of + Squares	Mean + Square	F Value	Prob.
Treat.(PKGS.)	2	1.72	0.86	1.01	0.39
Storage	4	15.29	3.82	4.49*	0.01
Interaction	8	0.77	0.10	0.11	
Error	15	12.77	0.85		

+ These values are multiplied by 10^4.
* Significant @ p= 0.05 level.

Table -12. Analysis of variance for Gumminess in simulated baked potato product stored unpackaged, in low density polyethylene, or laminated retortable pouches.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob.
Treat.(PKGS.)	2	6.18	3.09	189.45**	0.00
Storage	4	1.60	0.40	24.45**	0.00
Interaction	8	0.44	0.06	3.39*	0.00
Error	15	0.24	0.02		

* Significant @ p= 0.05 level.
** Significant @ p= 0.01 level.

APPENDIX - D

Table -13. Changes in the moisture of the skin for simulated baked potato product in different packaging materials within time of storage.

Treatment	Mean#
W/O	37.23a
LDPE	51.10a
R.P	52.71a
SEM	2.14

W/O = without packaging
LDPE = packaged in low density polyethylene.
R.P = packaged in laminated retotable pouch.
# Mean is calculated from 6 values.
Means within columns having different letters are significantly different (p=0.05).

Table -14. Changes in the interior moisture for simulated baked potato product in different packaging materials within time of storage.

Storage time Treatments	2nd Month Mean#	3rd Month Mean#	4th Month Mean#	5th Month Mean#	6th Month Mean#	7th Month Mean#
W/O	76.36 a	75.94 a	74.47 b	74.04 b	72.44 b	71.01 b
LDPE	77.40 a	76.14 a	76.69 a	76.46 a	76.73 a	76.52 a
R.P	77.40 a	77.79 a	77.56 a	77.93 a	76.10 a	76.84 a
SEM	0.57	0.57	0.57	0.57	0.57	0.57

W/O = without packaging
LDPE = packaged in low density polyethylene.
R.P = packaged in laminated retotable pouch.
# Mean is calculated from 6 values.
Means within columns having different letters are significantly different ($p=0.05$).

Table -15. Changes in the color L value for simulated baked potato product in different packaging materials within time of storage.

Storage time Treatments	2nd Month Mean#	3rd Month Mean#	4th Month Mean#	5th Month Mean#	6th Month Mean#	7th Month Mean#
W/O	70.53 ab	69.70 a	64.75 c	63.00 c	62.85 b	60.38 c
LDPE	71.46 a	70.40 a	68.02 a	67.90 a	65.80 a	69.50 a
R.P	69.85 b	67.20 b	66.35 b	66.20 b	66.35 a	66.55 b
SEM	0.27	0.27	0.27	0.27	0.27	0.27

W/O = without packaging
LDPE = packaged in low density polyethylene.
R.P = packaged in laminated retotable pouch.
# Mean is calculated from 6 values.
Means within columns having different letters are significantly different (p=0.05).

Table -16. Changes in the color b value for simulated baked potato product in different packaging materials within time of storage.

Storage time Treatments	2nd Month Mean#	3rd Month Mean#	4th Month Mean#	5th Month Mean#	6th Month Meam#	7th Month Mean#
W/O	15.95 a	16.50 a	17.35 a	17.90 a	16.30 a	17.15 a
LDPE	15.95 a	16.45 a	16.95 a	16.60 b	16.25 a	16.35 b
R.P	16.00 a	16.70 a	17.30 a	16.80 b	16.65 a	17.10 a
SEM	0.18	0.18	0.18	0.18	0.18	0.18

W/O = without packaging LDPE = packaged in low density
R.P = packaged in laminated polyethylene.
retotable pouch.
Mean is calculated from 6 values.
Means within columns having different letters are significantly different (p=0.05).

Table -17. Changes in the Adhesiveness for simulated baked potato product in different packaging materials within time of storage.

Storage time Treatments	2nd time Mean#	4th time Mean#	5th time Mean#	6th time Mean#	7th time Mean#
W/O	1.10 a	1.45 a	1.81 a	1.20 b	0.53 b
LDPE	1.32 a	1.74 a	1.85 a	2.07a	1.17 a
R.P	1.16 a	1.29 a	0.58 b	1 51 b	1.40 a
SEM	0.13	0.13	0.13	0.13	0.13

W/O = without packaging
R.P = packaged in laminated retotable pouch.
LDPE = packaged in low density polyethylene.
# Mean is calculated from 6 values.
Means within columns having different letters are significantly different (p=0.05).

Table -18. Changes in the Firmness for simulated baked potato product in different packaging materials within time of storage.

Storage time Treatments	2nd month Mean#	4th Month Mean#	5th Month Mean#	6th Month Mean#	7th Month Mean#
W/O	13.56 a	13.66 a	13.44 a	15.90 a	17.72 a
LDPE	5.38 b	6.61 b	6.92 b	11.60 b	11.77 b
R.P	5.35 b	7.75 b	6.32 b	7.18 c	8.15 c
SEM	0.37	0.37	0.37	0.37	0.37

W/O = without packaging
LDPE = packaged in low density polyethylene.
R.P = packaged in laminated retotable pouch.
# Mean is calculated from 6 values.
Means within columns having different letters are significantly different (p=0.05).

Table -19. Changes in the Gumminess for simulated baked potato product in different packaging materials within time of storage.

Storage time Treatments	2nd Month Mean#	4th Month Mean#	5thMonth Mean#	6th Month Mean#	7th Month Mean#
W/O	1.88 a	1.95 a	1.83 a	2.33 a	2.54 a
LDPE	0.82 b	1.17 b	1.18 b	1.62 b	1.67 b
R.P	0.74 b	1.18 b	1.05 b	1.07 c	1.17 c
SEM	0.09	0.09	0.09	0.09	0.09

W/O = without packaging
LDPE = packaged in low density polyethylene.
R.P = packaged in laminated retotable pouch.
# Mean is calculated from 6 values.
Means within columns having different letters are significantly different ($p=0.05$).