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RECOVERY, ANALYSIS AND UTILIZATION OF POTATO PEEL

By

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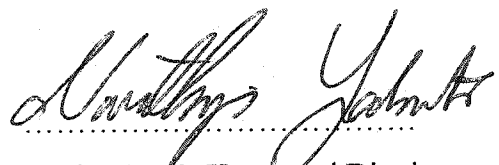
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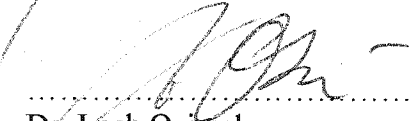
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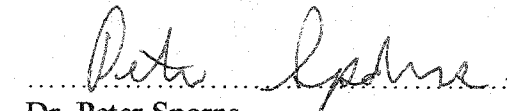
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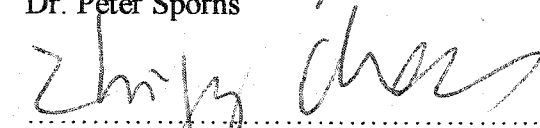
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The undersigned certify that they have read, and recommend to the Faculty of Graduate

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fulfillment of the requirements for the degree of Master of Science in Food Science and

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# Abstract

Potato peel from a steam peeling process was recovered and analyzed for glycoalkaloids, dietary fiber, and starch. The results show 1.18 μg of α-chaconine and 0.62 μg of α-solanine per g of peel, 56.61% insoluble and 4.48% soluble dietary fiber, and 15.70% starch. The peel was mixed with mashed potatoes and some hydrocolloids and baked into the shape of a half-tuber shell resembling a real baked potato shell. A reformed potato product was then made by filling the shell with mashed potatoes. The product was stored frozen and was reheated in either microwave or regular oven before serving. Sensory properties of the product were evaluated in comparison with a control made from scooped-out baked potato shells refilled with mashed potatoes. Results show that the product made with edible shells containing 2.5% potato peel was preferred to the control.

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# CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW

## A. Introduction

In Canada, approximately 4.5 million tonnes of potatoes are processed each year (FAO, 2002), most of which are peeled before processing. Consequently, 10-20 % of the potato is discarded during peeling (Smith and Huxsols, 1975), creating a considerable amount of potato peel (PP). Even though PP may be used as compost or animal feed, production outpaces such utilization. PP is currently dumped in the waste stream, generating pollution and waste treatment load. However, increasing waste disposal costs limit this option for potato processors.

Research has been conducted to explore the use of PP as a source of dietary fiber. Toma *et al.* (1979) studied the physical and chemical characteristics of PP. They reported that PP was apparently superior to wheat bran in total dietary fiber, water holding capacity and low quantity of starchy components. Camire and Flint (1991) found that PP contains 45% dietary fiber and Camire *et al.* (1993) reported that PP fibers are primarily insoluble, and can bind bile acids *in vitro*. It is believed that bile acid-binding is one of the mechanisms whereby certain sources of dietary fiber lower plasma cholesterol. Lazarov and Werman (1996) studied the hypocholesterolaemic effect a dietary fiber from PP. They found that after four week, rats fed with PP showed a 40% decrease in plasma cholesterol content and a reduction of 30% in hepatic fat cholesterol levels as compared with rats fed with cellulose.

PP contains 10 times the concentration of phenolic acids found in potato flesh (Malmberg and Theaoder, 1984). The PP extracts exhibited antioxidant effects in beef and sunflower oil (Rodriguez de Sotillo et al., 1998).

Some studies of the addition of PP to baked products as a source of dietary fiber has been conducted. Wheat flour was substituted with PP in white bread, but it increased crumb darkening and reduced loaf volume (Toma et al., 1979). Orr et al. (1982) found that PP caused a musty odor in breads, but extrusion can remove volatiles from PP at the extruder die. Abdel-Magied (1991) reported that biscuits containing 5% and 10% PP had decreased stack weight. Sensory scores (colour, and appearance) of PP- supplemented biscuits decreased as the percentage of PP increased. The supplemented biscuits were significantly harder to bite than control biscuits. Arora and Camire (1994) found that muffins with 25% PP were darker, lower in height and more resistant to compression, and cookies with 10% and 15% peels (w/w) were darker, harder and smaller in diameter than control cookies. Although there has been an increase in consumer interest in the health benefits of fiber, PP has not been widely used as a source of dietary fiber.

The presence of glycoalkaloids impedes the utilization of PP as ingredients in food products. The concentration of glycoalkaloids at 4-12 mg per 100 g fresh weight is considered to enhance potato flavor; however, a concentration greater than 20 mg per 100 g in flesh gives bitter taste and can cause gastroenteric symptoms, coma, and even death (Sotelo and Serrano, 2000). The principal glycoalkaloids in the PP are $\alpha$-chaconine and $\alpha$-solanine (Smith et al., 1996). Glycoalkaloids are heat stable and not destroyed under typical food processing conditions (Friedman and Dao, 1992). Zhao et al. (1994) found that extrusion cooking did not significantly reduce glycoalkaloids in PP. They also

suggested that PP may be incorporated into food products at a level of 18g/100 g of the final product without exceeding the recommended limit of 20mg of total glycoalkaloid /100 g of product.

Though there are some problems associated with the recovery and utilization of PP, it appears that further studies are needed in order to remove this potentially valuable by-product from the waste stream and use it in value-added products. Therefore, with Bassano Growers Ltd. agreeing to supply the raw PP, a research proposal was developed for this purpose. The objectives of this research were: 1) to develop a suitable method to recover potato peels from an industrial potato peeling operation; 2) to determine chemical composition of the recovered peel; 3) to develop an edible potato shell using the potato peel as an ingredient; and, 4) to develop a product resembling a filled or baked potato product using potato shell as an outer casing of the product, and evaluate its acceptability.

## B. Literature Review

### 1. Potatoes

#### 1.1 Potato production in Alberta

Potato was the most important vegetable crop in Canada. In 2000, potato crop accounted for 33% of all vegetable farm cash receipts in Canada, which totaled $670 million (Pearson, 2002). Approximately four million tonnes of potatoes are produced annually in the last six years. Over 50% of potatoes grown in Canada are processed, mostly into French fries. Ten to fifteen percent of the crop is utilized for chips and dehydration. Canada is second only to the Netherlands as the leading exporter of frozen fries (Agriculture and Agri-Food Canada, 2002).

In Alberta, potato production has been expanding since 1980s. Alberta continues to lead the growth of potato industry in Western Canada because of the expansion of potato processing plants especially frozen French fry processing between 1999 and 2000. Alberta produced 769,100 tonnes and was the third largest potato producing province next to Prince Edward Island and Manitoba (Agriculture and Agri-Food Canada, 2002).

According to the Potato Growers Association of Alberta (PGA), there are three categories of potato produced: 1) processing potatoes in which 90 percent of potatoes produced are used in the processing industry, especially frozen French fries, potato chips, and dehydrated potato granules, 2) seed potatoes and 3) table potatoes. The potato processing industry is currently based almost exclusively in southern Alberta (Pearson, 2002).

## 1.2 Potato peeling process

Peeling is one of the most important steps in potato processing. The method and efficiency of peeling affect the yield of finished product, the amount of waste and the cost of waste disposal. Potatoes are commercially peeled by either abrasion, high pressure stream, or caustic peeling (Sieczka, 2000). The end product desired determines the peeling method used. For example, if the potatoes are to be sliced for French fries, or diced for potato salad, the peeling is not as critical and small surface defects or color around the potato eyes can be tolerated. On the other hand, the whole peeled potatoes for canning and freezing must be cleanly peeled and almost totally free from surface defects (Smith and Huxsoll, 1987). The peeling losses, associated with various potato products, are shown in Table 1.1.

**Table 1.1. Typical peeling losses associated with various potato products**

| Product | Loss through peeling (%) |
| --- | --- |
| Canned small potatoes | 40-50 |
| Prepeeled potatoes for restaurants | 20-30 |
| French fries | 10-20 |
| Dehydrated mashed potatoes | 5-10 |
| Potato chips (early season) | 2-5 |
| Potato chips (late season) | 8-12 |

From Smith and Huxsoll, 1987

### Abrasion Peeling

Abrasion peeling is commonly used in the potato chip industry, where very minimal peeling is required. This method is available either as batch-type units or continuous systems. Both systems use abrasive grits to grind the skin from the potatoes as sprayed water flushes away the loosened particles of peel. There is no problem of heat ring, the dark cooked-surface associated with cooked potatoes, because heat and chemical are not utilized. The most serious disadvantage of this method is the high peel loss that occurs when the end products require clean peeling. Approximately, the peeling losses of the potato chip industry, which uses abrasion peeling extensively, are 10% (Smith and Huxsoll, 1987).

### Steam Peeling

Steam peeling is one of the most popular among modern methods. In steam-peeling process, the steam under pressure is used to rapidly heat and soften the peel and the underlying surface tissue. The peel can be then removed with barrel-type washers with high-pressure water sprays, or by dry scrubbers using rotating rubber studded rolls. The advantages of this method are that they do not use lye, thus chemical water pollution is eliminated; peel losses can be reduced to low levels, and peel residues are directly suitable for animal feed. The disadvantage is the energy intensive nature of the process (Smith and Huxsoll, 1987). Time and temperature settings are critical to controlling depth of peel softening and removal in the steam process (Garrote *et al.*, 2000).

### Caustic (Lye) Peeling

Among the methods employed by potato industry, chemical peeling with NaOH is one of the oldest and most common. The selected method depends upon the type and variety of the products to be processed and the capacity of the industrial plant.

Caustic or lye peeling of potatoes combines the effect of chemical attack and thermal shock for the loosening and softening of the skin, blemishes, and eyes of potatoes to the extent that they may be readily rubbed or worked off by pressure spray washers or other mechanical action (Garrote *et al.*, 1998).

The basic caustic peeling process involves contacting wet, washed potatoes with a hot dilute lye solution followed by washing with high pressure water sprays in a barrel-type washer to remove the softened tissue. After washing, the peeled potatoes may be immersed in or sprayed with a dilute acid solution, such as citric acid, to neutralize any

residual caustic on the surface. However, if washing is sufficiently thorough, these acidic solutions are not needed. The peel from this process is unsuitable for animal feed due to its alkalinity (Smith and Huxsoll, 1987).

### 1.3 Potato peel as solid waste

The processed potatoes amount to over 4.0 million tonnes annually (Agriculture and Agri-Food Canada, 2002). If 10 % was lost in peeling (Sieczka, 2000), this would constitue 0.4 million tonnes of potato peel. Even though potato peel has been used as animal feed and compost (Natu, *et al*, 1991), production outpaces such utilization. There has been some research conducted on the utilization of potato peel waste. For example, the potato peels was used to grow mold hyphae. A combination of caustic potato peel waste and acidic wastewater from fish processing operation was suggested as animal feed (Natu, *et al.*, 1991). It has also been studied for the use as feed for pigs (Natu, *et al*, 1991). Milk fat of milk from cows fed with potato peel was reported to be 3.3 g/kg higher than that of control (Jurjanz *et al.*, 1998). PP was also reported to be an excellent substrate for enzyme glucoamylase production (Fadel, 1999).

### 2. Wastes from Food Industry

Food wastes are by-products and residues derived from food processes that are relatively low in value. The food industry produces large quantities of wastes, both solids and liquids, which results from the production, preparation and consumption of food. These wastes are expensive to collect, treat and dispose, and they represent a loss of

valuable materials (Kroyer, 1995). Food wastes vary considerably in composition, volume, and concentration depending on the food that is being processed (Table 1.2).

**Table 1.2. Amount of waste generated from processing of food**

| Processed food waste | Total solid (g/kg) | Liquid volume (m³/kg) |
|---|---|---|
| **Vegetables** | | |
| Peppers (caustic peeling) | 65 | 0.020 |
| Potatoes | 66 | 0.012 |
| Tomatoes (caustic peeling) | 14 | 0.010 |
| **Dairy** | | |
| Cheese whey | N/A | 9.00 |
| Skim milk | N/A | 0.07 |
| Ice cream | N/A | 0.08 |
| **Meat** | | |
| Red | 0.44 | 25.00 |
| Poultry | 0.27 | 50.00 |
| Eggs | 0.111 | N/A |

From Cybulska, 2000

All unit operations in food processing produce large amount of wastes, especially preliminary operations like cleaning, sorting and peeling (Niranjan and Shilton, 1994). Table 1.3 shows types of wastes at each processing steps in food processing.

Generally, wastes from the food processing industry have the following common characteristics: (a) large amounts of organic materials such as carbohydrates, proteins, and lipids, (b) large amounts of suspended solids depending on the source, (c) high

biological oxygen demand (BOD) or chemical oxygen demand (COD), (d) high nitrogen concentration, (e) high suspended oil or grease contents, and (f) high variation in pH (Kroyer, 1995).

**Table 1.3. Food processing operations and the physical state of the resulting wastes.**

| Operation | Method | Types of wastes |
|---|---|---|
| **Pre-processing operations** | | |
| Raw material transportation within the plant | Hydraulic Conveyers | Waste water |
| Cleaning of raw materials | Dry (screening, brushing, magnetic separation) | Solid contaminants |
| | Aqueous (soaking, spraying, fluming, flotation, setting) | Waste water with large solid content (suspended and dissolved) |
| | Chemical (surfactants etc) | Chemical contamination of water |
| Sorting and grading | - | Solid and particulate waste |
| Size reduction | Milling & crushing | Particulate waste |
| Peeling | Mechanical | Peel (solid waste) |
| | Water / stream | Peel, waste water |
| | Chemical (caustic) | Chemical contamination |
| **Processing operations** | | |
| Extraction | Expression, diffusion | Solid wastes and waste water |
| Blanching | Aqueous solutions (brine), steam | Salty waste water |
| Emulsification | Any method | Waste water containing oil/fat droplets |
| Filling and packaging | - | Food residues, waste water and packaging wastes. |

Adapted from Niranjan and Shilton, 1994

## 2.1 Liquid waste

The main type of waste produced by all sectors of the food processing is waste water. Water is used in food processing for many purposes: washing of incoming material, hydraulic transportation, grading and inspection, separation of debris from raw materials, incorporation into product, blanching, heating and cooling, and clean-up (Niranjan and Shilton, 1994).

Liquid waste from animal-based processing is strongly polluting the environment and can have adverse effects if discharged without adequate treatment. Waste water from meat processing contains blood, fats, organic and inorganic solids, salts and chemicals added during processing (Ockerman and Hansen, 2000). Liquid waste form seafood processing consist of blood, skins, viscera, condensate from the cooking operation and cooking water (Cybulska, 2000).

Wastes from the dairy processing include four major types: (a) milk from flushing and spills, (b) dairy products from machinery malfunction and retail returns, (c) whey from cheese and casein production, and (d) ultrafitration permeate from production of cheese and whey protein (Jelen, 1983).

More than 80 billion gallons of waste water are produced annually from processing a variety of fruits and vegetables in the USA. The water is used in washing, peeling, sorting and slicing, cooking, canning, and plant clean up (Hang, 2000). Table 1.4 shows the estimated volumes of wastewater if only fresh water were used in all the processing steps. Liquid waste from fruit and vegetable processing include carbohydrates, pectins, vitamin and cell walls and consist of 70-85% dissolved organic matter (Cybulska, 2000).

**Table 1.4. Source and volumes of wastewater from fruit processing steps**

| Operation | Wastewater (litre /tonne) |
|---|---|
| Peeling | 182 |
| Spray washing | 1457 |
| Sorting, slicing etc. | 454 |
| Exhausting of cans | 182 |
| Processing | 91 |
| Can cooling | 3577 |
| Plant cleaning | 3178 |
| Box washing | 265 |

From Hang, 2000

## 2.2 Solid waste

Solid wastes in food processing plants are generated from (a) preliminary peeling and cutting operations, (b) residues generated from the processing operations, (c) wastes resulting from processing inefficiencies, such as rejected materials and trimmings, and (d) the sludges degenerated during on-site effluent treatments (Niranjan and Shilton, 1994). Solid waste is also associated mainly with packaging materials (plastics, metals, wood and paper) (Nini and Gimenez-Mitsotakis, 1994). Although it is difficult to determine the amount of solid wastes from food processing industry, some of typical solid wastes generated from a selection of food processing areas are summarized in Table 1.5.

**Table 1.5. Examples of wastes produced in food processing**

| Processing Facility | Typical solid wastes |
|---|---|
| Meat processing | Vary on the type of animal, includes: Hide/skin, bone, intestines, hair, fats; parts not used (head, feet, intestines) |
| Seafood processing | Whole fish, skin, shells (in crab processing, up to 85% in waste) |
| Fruit and vegetable | Peels, stones, leaves |
| Dairy | Containers, dried milk, butter, buttermilk residues, cheese, whey, suspended solids |

From Cybulska, 2000

## 2.3 Packaging waste

Packaging performs three broad functions: protection, preservation, and presentation (Brown, 1993). Packaging maintains quality and shelf life of food by protecting food from interaction with its environment. Food packaging also provides important information to the consumer and enables convenient dispensing of food (Kroctha and De Mulder-Johnston, 1997). However, food packaging has been the target of environmental and consumer activist groups as being a major contributor to the solid waste pollution. Total municipal solid waste (MSW) generated in the United States was approximately 229.9 million tonnes in 1999. Containers and packaging comprised the largest portion of wastes generated at approximately 33% (76 million tonnes) (Table 1.6) of the total municipal solid waste (MSW). In addition, packaging wastes appear more significant because they occupy close to two third of MSW volume due to its bulk (EPA, 2000)

Packaging in Canada is comprised of 30% of the MSW being sent to landfills. Canadian creates one tonne of packaging waste per year per person. In 1989, 80% of this waste was landfilled or sent for incineration (Environment Canada, 1989). There are five main types of packaging waste in MSW in Canada:

- Corrugated boxes ~ 18.5 %

- Metal cans ~ 16%

- Other Paperboard Boxes ~14%

- Glass ~9%

- Plastics ~ 7%

- Other ~ 35.5%

**Table 1.6. United States packaging solid waste in 1999**

| Material | Tonnes (million) | Weight recovered (tonnes) | Recovered as a percent of generation |
|---|---|---|---|
| Steel | 2.9 | 1.7 | 57.3 % |
| Aluminum | 2.0 | 0.9 | 44.2% |
| Total metals | 4.9 | 2.6 | 52.0% |
| Glass | 11.1 | 2.9 | 26.6% |
| Paper & Paperboard | 41.2 | 21.0 | 51.0% |
| Plastics | 11.2 | 1.1 | 9.7% |
| Wood | 7.5 | 0.7 | 9.5% |
| Other materials | 0.2 | Neg. | Neg. |
| Total containers and packaging | 76 | 28.3 | 37.2% |

From EPA, 2000

Plastic packaging, in particular was perceived by the public as using valuable non-renewable natural resources and as being neither biodegradable nor recyclable. Consumers are also concerned about the environmental effects of disposable food service items, such as containers, plates, cups and utensils, as well as other plastic disposable items. According to the Environmental Protection Agency, USA, plastic packaging accounts for 4.8% of MSW or 11.2 million tonnes out of 229.9 million tonnes. However, only 9.7 % of plastic is recycled compared to those of aluminum, paper, and glass, which are 57.3%, 51.0%, and 26.6%, respectively.

## 3. Attempts at waste reduction

Waste from food processing industries, both solid and liquid, posed increasing disposal and potentially severe pollution problems. The solid wastes are often used as animal feed, spread on land for used as a fertilizer, or disposed of to waste management

facilities (Cybulska, 2000). Nearly all of the liquid waste is disposed of in water (stream, lake, bay or ocean) and in public treatment facilities (Hang, 2000).

Generally, landfills and incineration are two major means of disposing of solid waste. The areas remaining for landfills are becoming acutely scarce and expensive, and the potential cause of ecological problems (Cage, 1991). Incineration is widely used in many parts of Europe such as Germany and Sweden; however, incineration requires high-cost equipment for dealing with high caloric-value waste and produces toxic gases such as HCl from polyvinyl chloride (Giffin, 1994).

The use of combustible MSW as energy source can replace the nonrenewable fossil fuel. In Canada, about 8.6 million tonnes combustible MSW are produced each year, and can easily be incinerated if the proper facilities are available. Unfortunately, although Canada has the highest rate of waste production per capita in the world, it has only 12 operating incinerators handling a very small fraction of the total MSW generated. The main bulk is sent to the landfill. In addition, recovering energy from waste is not an inexpensive source of energy. The initial investment and monitoring an incinerator is very high. The costs of operating, maintaining, and monitoring an incinerator are substantial compared to those for a conventional power plant (Managhi, 1993). Environmental regulation, closure of landfill sites, and higher waste management costs are forcing the consideration of other options.

### 3.1 The 3R's Concept

The hierarchical three R's concept (reduce, reuse, and recycle) are being promoted by several nations, and appears to be the most logical and promising approach for dealing with present waste management problems.

### Reduce

"Reduce" means reducing the amount of waste produced at source (Murray, 1995). Examples of waste reduction include reducing rejected products in manufacturing processes, minimizing water consumption and effluent generation, and reducing packaging use (Brown, 1993). The processing waste created at source can be reduced through the development of improved processing methods. For example, the peeling operation represents the most important single production source of waste in fruit and vegetable processing. The peeling process creates approximately 4,600 kg of total solids/day, whereas the dry-caustic peeling process produces only about 480 kg of total solids per day (Table 1.7). Furthermore, the dry-peeling reduces the BOD load from 1,200 to 86 kg/day (Hang, 2000). Dry peeling has also found commercial application in the peeling of white potatoes, sweet potatoes, beets, carrots, tomatoes and peaches (Laughlin *et al.*, 1984).

The pollutant loads from blanching are significant portion of the total load in the effluent stream during the processing of some vegetables (Bomden, 1979). Blanching is responsible for 35% of the total BOD for corn, and 31% of the total BOD of blanched vegetables. As an average, blanching accounts for approximately 40% of the waste load of a vegetable canning plant (Laughlin *et al.*, 1984). As a result, a hot gas blanching was

developed for vegetable processing. Hot gas blanching reduces the volume of vegetable

processing wastewater, suspended solids, and BOD (Robe, 1973).

A number of methods used to reduce the amounts of wastewater discharged are

available. These include modernizing water sprays to include jets or nozzles, using high-

pressure low volume washing systems, the use of auto shut-off valves on water hoses,

and the countercurrent reuse of wash/flume/cooling water (Hang, 2000).

**Table 1.7. Water usage and properties of wastewater in two different peeling operations of beets.**

| Measurement | Conventional peeling | Dry-caustic peeling |
|---|---|---|
| Raw beets, input, tonne/day | 80 | 80 |
| Water flow rate, litre/day | 181,700 | 45,425 |
| Total solids, kg/day | 4,627 | 476 |
| Soluble solids, kg/day | 154 | 18 |
| BOD, kg/day | 1,211 | 86 |

From Laughlin *et al*, 1984

The packaging source reduction has emerged to reduce food packaging wastes

successfully. The emphasis of packaging reduction is on minimization of films or

container thickness, and the elimination of excess material through improved design with

packaging minimization often achieves the desirable combination of reduced costs and

reduced environmental impact, and so it has made an impressive progress. For instance,

between 1975 and 1990 the typical weight of a 1.5l PVC bottle fell by 27%, and that of a

PET bottle fell by 33%; polyethylene bread bags have been reduced to a thickness of 25-

28 μm from an earlier thickness of 40 μm (Brown, 1993).

Canada's National Packaging Protocol (NAPP) set a base year of 1988 for

packaging waste reduction goal of 50% for the year 2000, and challenged Canadian

industry, particularly the soft drink industry, to find ways to reduce packaging use. By 1992, more than half of the soft drink industry's packaging reduction was accomplished at the source. Furthermore, total packaging set for disposal in Canada during 1996 was decreased to 2.64 million tonnes, compared to 5.41 million tonnes in the base year (1988). This level of reduction was achieved by reduction in packaging materials used. For example, the weight of 2-L plastic PET soft drink bottles has been reduced by 31%; aluminum cans are 27% lighter than they were in 1979, and plastic strapping has been replaced by stretch wrap used to stabilize bottle shipping cases stacked on reusable wooden shipping pallets (Katz, 1998).

**Reuse**

"Reuse" implies using of the material again. It is known that at least 50 to 60% of normal consumption in a food processing plant can be saved for reuse (Niranjan and Shilton, 1994). For example, water from the can-cooling operation can be used for cleaning the equipment. Reduction in the volume of fresh water consumed will result in reduction of the volume of wastewater to be treated (Hang, 2000).

In addition, the reusable packaging is a growing concept in the food industry. Well-known examples include reusable shipping crates, pallets, or storage containers, and refillable bottles (Brown, 1993). Reusable packgaing has vast economic benefits including reduction of packaging costs, reduction of solid waste, and improved productivity and lower labor costs (Rothfuss, 1997).

**Recycle**

Unlike reuse, the recycle of any material requires further processing. Recycling turns materials that would otherwise become waste into valuable resources and generates a host of environmental, financial, and social benefits. After collection, materials (e.g., glass, metal, plastics, and paper) are separated and sent to facilities that can process them into new materials or products. Recycling helps reduce the amount of raw virgin material, energy usage, and the amount of waste going to landfill and incineration (Arvanitoyannis and Bosnea, 2001).

In the USA, recycling is one of the best environmental success stories of the late 20th century. It diverted 64 million tonnes of material away from landfills and incinerators in 1999, from 34 million tonnes in 1990 (EPA, 2000). In Japan, liquid and solid food processing wastes are recycled at both on and off site facilities. The food industry is recycling about 6.6% of its waste on-site, while an additional 31.5% was recycled by industrial waste management contractors. Cooking oil was often recycled on-site as fuel; whereas plastics, scrap metals and glass were usually recycled by industrial management contractors (Okamoto and Ushikubo, 2001)

In Canada, 10% of garbage is currently recycled, and despite temporarily unreliable markets for certain recyclable commodities (e.g. glass and newspaper), more and more municipalities are adopting recycling programs, which can only improve the prospects for waste reduction (Murray, 1995). In 1998, waste per capita in Canada was reduced to 56%, equivalent to 11.7 million tonnes. This has been achieved because several industries have adopted the 3-R approach of 'reduce, reuse, recycle. Both weight and size of transport and consumer packaging have been radically reduced. About 2/3 of

the reduction was realized by reuse of materials such as pallets. Increased recycling has also contributed to the numbers of recycling plants growing rapidly (Menzies, 1998).

### 3.2 Recovery and utilization of food industry waste

The waste from the food industry is treated biologically involving the use of aerobic filters, trickle beds and activated sludge technology (Hang, 2000). However, only detoxification and usually no useful by-products are obtained. Under anaerobic conditions, food-processing wastes containing carbohydrates, lipids and proteins can be digested to yield biogas, which in turn can be used as a fuel to supply heat and light, for example. Most of the full-scale installations of this sort are within the sugar processing, meat rendering, brewing and distilling, bottling and soft drinks, wheat-starch and potato processing industries (Kroyer, 1995). Ethanol or organic acids can be produced from carbohydrate containing waste materials by anaerobic microbiological processes (Hang, 2000). Much effort has been made to produce waste materials to more valuable products by using appropriate biotechnical processes; the production of biomass, namely single cell protein (SCP), and the production of ethanol seem the most promising (Nigam *et al.*, 2001). The followings are examples of waste recovery and utilization.

**Meat wastes**

Common by-products recovered from meat processing operations are blood, hide, bone, offal, and feathers. For instance, blood is used commercially for microbial growth media, extraction of animal albumin, and animal feed protein. Inedible meat materials are salvaged for use in pet and animal foods or sold for rendering purposes (Chambers, 2000).

Owing to the increasing demand for protein, much research have been conducted to develop processes in order to produce value-added products from high-protein meat and fish processing wastes which currently may be used as an animal feed or are lost from the food chain altogether. Various microorganisms include yeasts, filament fungi, bacteria and algae, can be used to produce single cell protein. Moreover, slaughter house blood, a protein-rich residue can be utilized for the recovery of applicable protein preparations such as the iron containing heme fraction which can be used as a dietetic ingredient for specialized food or clinical products. Meat packing plants may also consider anaerobic digestion processes for the production of biogas (Nigam *et al.*, 2001).

**Dairy wastes**

The ideal situation is to reuse any milk, cream, or product recovered from the processing operations. This requires strict sanitary practices to avoid contamination.

In cheese manufacturing sector, sweet whey is recovered and used to make whey powder, whey proteins, lactose, and delactosed whey powder (Jelen, 1983). Membrane technologies are applied extensively for whey protein recovery and demineralization (Matti, 2001). Whey is also used widely as a milk replacer for veal calf operations

(Chambers, 2000). Typically, the dairy industries use salvage, pool and isolate recovered whey and dairy products for use as animal feed. Moreover, by utilization of whey, products such as ethanol, butanol, methane, single cell protein, enzymes (β-galactosidase), antibiotic, vitamins (L-ascorbic acid, B12, B6, B2), organic acids (lactic acid, citric acid) and food gums can all be produced (Nigam *et al.*, 2001).

### Fruit and Vegetable wastes

Fruit and vegetable processing wastes contain considerable organic matter, and disposal of these wastes may pose many environmental pollution problems. However, the industry has continued to make progress in solving the waste problems through the recovery of by products and waste materials. For example, most fruit and vegetable-processing solid residues are currently used for animal feed. They may be fed fresh, as silage, or as dried waste solids. Citrus, pineapple, and potato processing residues are almost entirely fed to animals. Other fruit and vegetable residues, nonetheless, are not used in animal feed rations due to their short processing season (Hang, 2000).

Natural food ingredients can be isolated from fruit and vegetable-processing wastes. For example, citrus and apple processing solid wastes provide a good source of raw material for commercial production of pectins (Heerden *et al.*, 2002). Colorants including lycopene and beta-carotene can be produced from tomato paste waste by using supercritical $CO_2$ extraction (Baysal *et al.*, 2000). Anthocyanins, tartrates, and grape-seed oil have been directly extracted from grape pomace (Hang, 2000). New types of seed oil were extracted from apple and kiwi seeds (Kennedy, 1994). These specialty oils would be

used in cosmetics; however, their recovery required the development and implementation of the seed recovery systems.

Attempts are now being made to isolate health-promoting dietary fiber and other phytochemicals from fruit and vegetable residues. McKee and Latner (2000) reviewed the underutilized sources of dietary fiber. Many of the dietary fibers, which have been researched, are obtained from by-products resulting from the processing of fruits, vegetables, legumes and other food products. Increased use of fiber supplementation would therefore not only improve the health benefits, but could also provide ecological benefits to food producers.

Fruit and vegetable processing wastes can be fermented to biofuels, namely, ethanol and methane (Joshi and Sandhu, 1996). Citric acid is commercially produced from fruit and vegetable processing residues by *Aspergillus niger* (Hang and Woodams, 2000). Some commercial enzymes can be directly extracted from fruit and vegetable processing residues. Research has been conducted to utilize these wastes as a substrate for fermentative production of industrial enzymes by food grade microorganisms (Antov *et al.*, 2001; Fadel, 1999). For example, wastes from the potato chips industry (rejected fresh potato, potato peels and sorted potato chips) were used successfully for the production of thermostable alpha-amylase (Fadel, 1999). Cellulases were produced from banana fruit stalk waste by solid-state fermentation (SSF) of *Bacillus subtilis* CBTK 106 (Chandukkadu, 1999). Tea wastes (the powder left after tea processing) was used as a solid substrate for *Aspergillus niger* fermentation for production of glucoamylase (Selvakumar *et al.*, 1998).

### 3.3 Edible and Biodegradable Packaging

Edible and biodegradable packaging has attracted an increasing amount of research and industry attention as an alternative form of food packaging with reduced environmental and waste disposal costs.

#### 3.3.1 Definition of edible packaging

Edible packaging can be in either rigid form like ice cream cone or in flexible form. Edible films and coating are generally defined as thin layers of edible material that are applied on (or within) food products to extend shelf life by inhibiting migration of moisture, oxygen, carbon dioxide, aroma, and lipids, depending on types of food products. In addition, they can modify characteristics of the food. They also act as carriers for food additives (e.g. antioxidant, antimicrobial, and flavoring). In certain cases, the edible film with good mechanical properties can partially or completely replace synthetic packaging films (Gennadios *et al.*, 2000).

#### 3.3.2 Definition of biodegradable packaging

Biodegradable packaging can be defined as packaging made from natural biopolymer obtained from renewable biological raw materials such as starch and bioderived monomers (Petersen *et al.*, 1999). Biodegradable materials must be degraded completely by microorganisms in a composting process to only natural compounds such as carbon dioxide, water, methane and biomass (Krochta and De Mulder-Johnston, 1997). The American Society of Testing and Materials (ASTM) provides standard guide for assessing the compostability of environmentally degradable plastics (ASTM D6002-96).

According to ASTM procedures, biodegradability of materials can be observed in 30 to 60 days in soil contact test (ASTM D5988-96).

### 3.3.3 Characteristics of edible and biodegradable packaging

In order to fabricate films or containers, the formulations must include at least one component able to form an adequately cohesive and continuous matrix. These components are macromolecules that are either synthetic, from which most current packaging is produced, or natural biopolymer. These biopolymers can be classified in four general categories: polysaccharide, proteins, lipids and polyesters (obtained by controlled vegetal or bacterial biosynthesis). Films primarily composed of polysaccharides (cellulose and derivatives, starch and derivatives, gums, etc.) or protein (zein, whey, casien, etc.) have suitable overall mechanical and optical properties, but are highly sensitive to moisture and exhibit poor water vapor barrier properties. Conversely, films composed of lipids (waxes, lipids or derivatives) or polyesters (poly-D-$\beta$-hydroxybutyrate, polylactic acid, etc.) have good water vapor barrier properties, but are relatively inflexible. Lipid film could be also fragile and susceptible to rancidity (Gontard and Guilbert, 1994).

### 3.3.4 Materials used for manufacture of edible and biodegradable packaging

Materials mainly composed of polymers of agricultural origin (in natural state or fractionated, e.g. whole grain, flours, proteins, starch, etc.) as well as food processing by products or wastes have been proposed. These natural polymeric materials, broadly classified according to the method of production, are as follows:

1. **Polymers directly extracted or removed from natural materials.** Examples are polysaccharide such as starch and cellulose (Glenn, *et al.*, 2001), and protein like whey (Anker *et al.*, 2000) and soy protein (Foulk and Bunn, 2001).

2. **Polymers produced by chemical synthesis from renewable bio-derived monomers.** A good example is polylactate, a biopolyester polymerized from lactic acid monomers. The monomer itself is produced by fermentation of carbohydrate feed stock (Fang and Hanna, 1999).

3. **Polymers produced by microorganisms or genetically transformed bacteria.** The best known biopolymer types are the Polyhydroxyalkanoates, mainly polyhydroxy-butyrates (HB) and copolymers of hydroxy-valerate (HV). Such copolymers are produced by Monsanto and are better known by the generic trade name "Biopol". Polyhydroxyalkanoates function in microorganisms as energy substrates and for carbon storage (Petersen *et al.*, 1999).

## Polysaccharide

### Cellulose-based polymer

Cellulose is the most abundant natural polymer in the world because it is the principal cell wall of higher plants. It is a high-molecular weight, linear, insoluble homopolymer of repeating β-D-glucopyranosyl units joined by $1 \rightarrow 4$ glycocidic linkages (Bemiller and Whistler, 1996). Films cast from sugar beet cellulose microfibrils have been investigated for mechanical properties (Dufresne *et al.*, 1997). Cellulose can be chemically modified to produce cellulose ether-ester films with moderate strength and grease and oil resistance (Arvanitoyannis and Biliaderis, 1999).

### Cellophane

Cellophane was the first transparent, flexible packaging film derived from cellulose. It is biodegradable but not edible. Cellophane makes a strong package because of its good elongation and tensile strength, but tear strength is poor. In addition, it has excellent printability, good machinability, excellent grease, oil and oxygen barrier (Hanlon *et al*, 1998).

Like other natural polymers, cellophane is very sensitive to moisture, expanding and contracting as the humidity changes. It is also not thermoplastic, and thus it is not heat-sealable. Because of these disadvantages, cellophane is often coated (e.g. with polyvinylidene chloride, nitrocellulose, and vinyl acetate/vinyl chloride) and is additionally laminated with low density polyethylene (LDPE) and oriented polypropylene (OPP) (Hanlon *et al.*, 1998).

### Cellulose acetate

Unlike cellophane, cellulose acetate is a thermoplastic material. Films can be produced by extrusion or solvent casting. Cellulose acetate films are clear and have good mechanical properties. Barrier properties against moisture and gases are not good, but cellulose acetate film is excellent for certain high-moisture products because it breathes and does not fog up. Cellulose acetate is also a good barrier to greases and oils. This material is not edible, but it slowly biodegrades (Krochta and De Mulder-Johnston, 1997).

. Cellulose acetate can also be used as active packaging. In the study of bitterness reduction in grapefruit juice through active packaging, cellulose acetate film immobilized with enzyme naringinase reduced bitterness as perceived by a sensory panel (Soares and Hotchkiss, 1998).

### Cellulose derivatives

Cellulose may be derivertized from the solvated state, by esterification or etherification of individual hydroxyl groups on the polysaccharide backbone. Water-soluble cellulose ethers have been evaluated to use as edible films and coatings including methyl cellulose (MC), hydroxypropylmethy cellulose (HPMC), hydroxypropyl cellulose (HPC), and carboxymethy cellulose (CMC). These cellulose derivatives are good barriers to oxygen, carbon dioxide and lipids, but poor barriers to water migration (Williams and Mittal, 1999). Their hydrophilicities increase in the order of HPC < MC< HPMC < CMC (Gennadios et al., 2000). Edible coating and films, which include MC, HPMC, HPC and CMC, have been applied to a variety of foods to provide a moisture,

oxygen, or oil barrier (Krochta and De Mulder-Johnston, 1997, Williams and Mittal, 1999). MC and HPMC have been used as edible coating for deep-fat frying of mashed potato balls. The reduction of 61.4% and 83.6% fat uptake was observed for samples coated with HPMC and MC films respectively (Balasubramaniam *et al.*, 1997).

**Starch**

Starch is the second-largest biomass produced on earth. It can be obtained in granular form from corn, wheat, potato, rice, cassava, yam and barley. Starch is a mixture of amylose, which is essentially a linear chain of $(1 \rightarrow 4)$ linked -glucospyranosyl units with a few $\alpha$-D- $(1 \rightarrow 6)$ branches, and amylopectin, which is very large, very highly branched molecules, with branch-point linkages constituting 4-5% of the total linkages (Bemiller and Whistler, 1996). The ratios of amylopectin to amylose vary according to starch types. Approximately, 27% of total starch usage is for nonfood purposes, namely in the paper, packaging, and textile industries (Raiz, 1999). The starches can be used to form edible or biodegradable packaging.

Both amylose and amylopectin can form films, but amylose films have better mechanical and barrier properties than amylopectin films (Rindlav-Westling *et al.*, 1998). They were excellent oxygen barriers, as good as the commercial ethylene vinyl alcohol films under ambient humidity (Forssell, *et al.*, 2002). Amylose, high amylose starch and hydroxypropylated high amylose starch have been used to form self-supporting films by casting from aqueous solution. (Krochta and De Mulder-Johnston, 1997). Films based on starch have moderate gas barrier properties. Their mechanical properties are generally

inferior to synthetic polymer films. When a plasticizer, such as water, is added starch exhibits thermoplastic behavior (Petersen *et al.*, 1999).

The role of starch in biodegradable thermoplastic materials has been reviewed (Roper and Koch, 1990). Starch is not truly thermoplastic as most synthetic polymers; however, in the presence of plasticizers (water, glycerin, sorbitol, etc.) at high temperature (90-180°C) and under shear, starch readily melts and flows, allowing its use as extrusion, injection, compression or blow molding materials, similar to conventional synthetic thermoplastic polymers (Curvelo *et al.*, 2001).

Starch-based hinged lid food containers similar in appearance to clamshell containers made of extruded polystyrene (EPS) have been produced by baking starch dough in the compression-molding machine (Glenn *et al.*, 2001). Commercial and semi commercial biological materials including polylactate (PLA), polyhydroxybutyrate (PHB), wheat starch and cornstarch have been investigated for use as films and cups. The mechanical properties (tensile strength, elongation, tear strength, compression, gas permeability ($CO_2$ and $O_2$) and water vapor permeability (WVP)) of theses packaging materials were comparable to conventional materials such as polyethylene (PE) and polystrylene (PS). However, the starch-based materials have high WVP, and need improvement (Peterson *et al.*, 2001). Efforts are now being made to improve the mechanical properties of starch-based packaging materials.

**Starch composite**

The first commercial "biodegradable" plastics were developed using a technique involving extrusion mixing of granular native starch (5-20%), prooxidative and

autooxidative additives, and synthetic polymers (Guilbert *et al.*, 1997). Starch-polyethylene mixture can be processed by injection molding, extrusion, or film blowing for the production of films or bottles (Krochta and De Mulder-Johnston, 1997). The biodegradability of these polymers is controversial because the safety concerns arise related to early biodegradation of the starch component and subsequent migration into the food of plasticizers and other additives. In addition, these packaging materials take 3-5 years to disintegrate not biodegrade (Gontard and Guilbert, 1994).

Starch and polyvinyl alcohol (PVOH) have been blended to yield thermoplastic materials with properties superior to starch alone (Lawton and Fanta, 1994). However, these materials are very sensitive to moisture, and hydrophobation due to the addition of PVOH increase costs (Krochta and De Mulder-Johnston, 1997). The composites prepared with cornstarch and cellulosic fibers showed an increase of mechanical properties (Curvelo *et al.*, 2001).

**Other polysaccharide materials**

**Alginate**

Alginate films can be produced by evaporation of an aqueous alginate solution followed by ionic crosslinking with a calcium salt (Wong *et al.*, 1996). The films are produced by dipping or spraying aqueous sodium alginate solutions on food products, then followed by treatment with a calcium salt solution (Gennadios *et al.*, 2000). These films are good grease and oil barriers, but are poor moisture barriers. Even so, alginate coating film can reduce moisture loss in cheese (Kampf and Nussinovitch, 2000).

Alginate films served as a reservoir of moisture that selectively loses moisture first, thus preserving the moisture of the packaged products. Starch-alginate-based composite films can reduce moisture loss and retard lipid oxidation in precooked ground-beef patties due to good oxygen barriers of the films (Wu *et al.*, 2001).

### Carrageenan

The polysaccharide gum carrageenan, a galactose polymer, is extracted from Irish moss (*Chondrus cripus*) and from other species of red seaweeds. ι-, χ-, λ-carrageenan are commonly used in food applications (Bemiller and Whistler, 1996). Carrageenan coating films have been used to extend shelf life of meat and fish (Gennadios *et al.*, 1997). Similar to alginate films, carrageenan films reduce moisture loss, retard lipid oxidation, and can be served as carriers for antimicrobial agents and antioxidants (Wu *et al.*, 2001)

### Pectin

Pectins are extracted mainly from apple pomace and citrus peel. They are composed of primarily methyl esters of linear chains of $1 \rightarrow 4$-α-D-galacturonic acid units. Low methoxyl pectin forms gels in the presence of calcium ions and can be used to develop edible films (Anker, 1996). Pectin films have quite high water vapor permeability as that of other carbohydrate films. Like alginate and carrageenan coating films, pectin coatings can retard water loss from food by acting as a sacrificing agent. Fishman *et al.*, (2000) investigated the extrusion of pectin/starch/glycerol (PSG) blends into edible and biodegradable films for potential use in food packaging. They concluded

that mechanical properties (the elongation strength) of extruded pectin/starch/glycerol (PSG) films were comparable to PSG films cast from solution, and these films would be suitable for food packaging applications.

### Chitosan

Chitin and chitosan are a naturally occurring biopolymer present in the exoskeleton of invertebrates, and they are the second most abundant structural polysaccharide next to cellulose. They are produced industrially from crustacean shell wastes. Chitin is composed of repeating units of 1,4-linked 2-deoxy-2-acetamido-$\beta$-D-glucose. Chitosan refers to a family of polymers derived from chitin that have been deacetylated to make them soluble in aqueous acidic solutions (Kittur et al., 1998). They are approved to be used in Canada and Japan, but have not received approval by the FDA in the United States (Gennadios et al., 2000).

Chitosan films can be produced from aqueous solutions (acetic, formic, or dilute hydrochloric acid solutions), and their water vapor and ethylene permeability as well as tensile strength were examined (Butler et al., 1996). The films are clear, tough, flexible and good oxygen barriers. Kittur et al. (1998) found that chitosan films crosslinked by treating with aldehyde under acidic conditions possessed greater oxygen permeability and poorer mechanical properties (tensile strength, tear resistance, and burst resistance).

Chitosan based films can inhibit the growth surface spoilage bacteria in processed meats (Ouahara et al., 2000). In the studies of the effectiveness of chitosan films and coatings against moisture loss in precooked beef patties, it was found as effective as PVC films in reducing moisture loss (Wu et al., 2001).

**Protein-based materials**

Proteins either from plants protein or animals s have gained attention as degradable, renewable polymers. Formation and properties of films from animal and plant proteins, such as collagen, gelatin, milk protein, wheat gluten, soy protein, corn zein, and peanut protein, have recently been reviewed (Shih, 1998; Gennadios *et al.*, 2000).

In general, protein-based biopolymers are good film formers exhibiting excellent oxygen, carbon dioxide and lipid barrier properties, particularly, at low relative humidites. Due to their hydrophilicity, they have poor water barrier characteristics. Protein film mechanical properties can be improved by regulating the degree of plasticization (McHugh, 2000).

**Collagen**

Collagen is a fibrous, structural protein in animal tissue that can be converted into edible and biodegradable films. Collagen films can be made by extruding a viscous colloidal acidic dispersion into a neutralizing bath followed by washing and drying. Collagen based films are not as strong and tough as cellophane but possesses reasonably good mechanical properties. Even though no data on the water vapor permeability of this film are available, its composition suggests that it is not a good moisture barrier (Krochta and De Mulder-Johnston, 1997).

Collagen is the most commercially successful edible protein film. Collagen casing have largely replaced natural gut casing for sausages. The films provide mechanical integrity to a meat product, and also function as an oxygen and moisture barrier. Besides

the sausage casing, collagen-based films can be used on netted roasts, boneless hams, fish fillets and roast beef (Gennadios *et al.*, 2000).

## Gelatin

Gelatin is obtained by hydrolytic cleavage of collagen chains. Gelatin films are largely use in microencapsulation of ingredients and manufacture of tablet and capsule coatings (Gennadios *et al.*, 1997). Gelatin can reduce oxygen, moisture, and oil migration or can carry an antioxidant or antimicrobial (Krochta and De Mulder-Johnston, 1997). Gelatin coating improved oxidative and colour stability of cooked ham and bacon during frozen storage (Villegas *et al.*, 1999).

## Milk proteins

Edible films and coating from casein, whey protein and total milk proteins have been discussed in detail (McHugh and Krochta, 1995). Cast films have been produced from both whey proteins (Sothornvit and Krochta, 2001; Fang *et al.*, 2002) and caseins (Mauer *et al.*, 2000). Whey protein isolate (WPI) has been found capable of forming transparent films and coatings that provide excellent oxygen, aroma and oil barrier properties at low relative humidity (RH) (Sothornvit and Krochta, 2001). Whey protein-based coatings have been tested on breakfast cereals, raisins, frozen peas, and cheese pieces (Avena-Bustilloss *et al.*, 1993). Whey protein coatings retention of potassium sorbate on whey protein films is higher than that of edible wheat gluten and LDPE films. Ozdemir and Floros (2001) concluded that whey protein films carrying potassium sorbate could be used on food surfaces as active-edible preservative releasing systems. Moreover,

whey protein coatings have shown potential as oxygen barriers for dry roasted peanuts (Mate and Krochta, 1998).

Casein has been studied for use in the production of soluble pouches (Krochta and De Mulder-Johnston, 1997). Cross-linking with transglutaminase reduced water resistance and increase mechanical properties of milk protein films (Mingxia and Damodaran, 1999). Films prepared from $\beta$-casein, the most hydrophobic protein in milk, have been investigated. Mauer *et al.* (2000), found that $\beta$-casein films had lower water vapor permeability (WVP) values than caseinate-based film, and also lower than those of composite caseinate: lipid films.

A sodium caseinate/stearic acid emulsion coating formulation reduced white blush and respiration rate and increased water vapour resistance in minimally processed carrot sections. Application of casein film delayed loss of firmness and minimized losses in weight, and juice level of fresh fruits during storage (Shafiq-Alam and Shashi, 2001). Furthermore, caseinate coating combined with lipid protected fresh vegetables, dried fruits and vegetables, and frozen fish from moisture migration and/or oxidation (Krochta and De Mulder-Johnston, 1997).

### Cereal proteins

Film-forming properties of plant protein vary, depending on the protein's amino acid composition and molecular characteristics (Shih, 1998). Proteins from wheat, corn, and soybean are readily available, and films produced from these materials have been studied extensively (Gennadios and Weller, 1990). The proteins are normally dissolved or dispersed in suitable solvents, then, the resulting solutions or dispersions form free

standing films either on an air-liquid interface by surface dehydration and heat-initiated polymerization or on a plate by casting the mixture and subsequent solvent evaporation. In general, plant protein films are water sensitive and lack mechanical strength; however, they are good barriers against oxygen (Shih, 1998).

### Zein

Corn zein, the prolamin fraction of corn proteins, is essentially an underutilized by-product of the corn wet milling industry. It possesses unique thermoplastic and hydrophobic properties. It is highly resistant to water and grease, and unique in its ability to form odorless, clear and tough films (Fu *et al.*, 1999). Zein films have been prepared by peeling-off dried aqueous ethanol or aqueous acetone zein solutions cast on inert, flat surfaces (Budi Santosa and Padua, 2000) Pure zein films are very brittle, and plasticizers need to be added. Polyethylene glycol (PEG), oleic, linoleic, and lauric acids have been used as plasticizers to improve mechanical and barrier properties of zein-based films (Paramawati *et al.*, 2001, Budi Santosa and Padua, 1999, Lai *et al.*, 1997).

Protective coatings based on zein are commercially available for use on confectionary items, shelled nuts, and pharmaceutical tablets. Many recent studies have focused on development and properties of zein films (Budi Santosa and Padua, 1999; Rakatonirainy and Padua, 2001; Lai and Padua, 1998). Rakatonirainy *et al.* (2001) have evaluated the performance of zein films as biodegradable modified atmosphere packaging (MAP) materials for fresh broccoli. The results showed that zein films were effective gas barriers, allowing development of modified atmospheres inside the packed broccoli. Zein films have been used as barrier packagings for popcorn, tomatoes, cooked turkey and

shell eggs as well (Fu *et al.*, 1999). Zein-based films have also been explored to use as antimicrobial carrier films (Padgett *et al.*, 1998; Hoffman *et al.*, 2001).

### Wheat gluten

Wheat gluten films can be produced from heated alkaline gluten dispersions in alcohol-water mixtures. Film solutions have been prepared by adding wheat gluten to ethanol solution with glycerine as plasticizer and dispersing in ammonium hydroxide (Roy *et al.*, 2000). The resulting gluten dispersions were cast on flat glass plates, and free standing films were recovered after dying at ambient temperature. The films have limited resistance to water vapor, but they are good barriers for oxygen.

### Soy protein

Soy as film ingredient is advantageous due to relative abundance, biodegradability and its renewable nature. Soy protein films can be produced by heating aqueous soy protein dispersions to form surface films, or by depositing and drying soy protein film-forming solutions (Shih, 1998). Recent study showed that soy protein films could also be prepared by spinning soy protein isolate in a coagulating buffer (Rampon *et al.*, 1999). Eggs coated with soy protein isolate showed greater puncture strength than those of noncoated eggs (Xie *et al.*, 2002).

Soy protein in edible coating applications can improve batter adhesion and reduce moisture migration in raisins and dried peas (Krochta and De Mulder-Johnston, 1997). Edible film compositions containing soy protein isolate, pullulan and stearic acid were effective for retarding senescence in kiwifruits during post harvest storage (Xu *et al.*,

2001). Rayner *et al.*, (2000) have found that applications of soybean protein films for use as coatings reduce oil uptake to 50% in fried foods. Grease resistance of papers coated with soy protein isolate at greater than 2.0 kg/ream was equal to or lower than that of polyethylene laminates used for quick-service restaurant sandwich packaging (Park *et al.*, 2000).

### Other proteins

Peanut protein films can be made from peanut concentrate solutions at pH of 9.0 and dried at 90°C (Jangchud and Chinnan, 1999). Won-Seok and Han (2001) prepared pea-protein based edible films plasticized with glycerol. They concluded that physical and mechanical properties of the edible films were comparable with those of soy protein and whey protein films. The allergy from peanut protein films, however, has not been well studied. Fish myofibrillar proteins have also been evaluated for use as rigid agro-material packaging (Cuq *et al.*, 1999).

### Microbial polyesters

Poly-hydroxyalkanoates (PHA) possess the desirable physical and chemical properties of plastics conventionally derived from petroleum. These polymers can be produced by nutrient-limited fermentation of sugar feedstock. By controlling the growth medium, copolymer containing both hydroxyvalerate (HV) and hydroxybutyrate (HB) is obtained. The resulting copolymers poly(3-hydroxybutyrate)-co-(3-hydroxyvalerate) is thermoplastic and fully degradable (Yu *et al.*, 1998). Recent studies also show that the

PHA can be produced from food wastes (soy wastes and malt wastes) by a mixed culture of activated sludge microorganisms (Wong *et al.*, 2000).

A high content of polyhydroxybutyrate (PHB) provides a strong and stiff material, whereas polyhydroxyvalerate improves flexibilities and toughness. The PHB is relatively more hydrophobic than polysaccharide and protein, resulting in a material with a good moisture barrier, whereas the gas barriers are inferior. Even though these materials are biodegradable on soil contact, water resistant, and are readily processed in standard industrial plastic plants, the limitation is their high cost of production (Petersen *et al.*, 1999).

### Polylactic acid

Polylactic acid (PLA) is a thermoplastic, biodegradable polymer based produced by fermentation of simple sugars. A flexible, water-resistant film was prepared from PLA (Bastioli, 2001). Polylactates have good mechanical properties similar to polyethylenterephthalate (PET) and polypropylene (PP). The moisture barrier property of polylactates is better than that of starch-based materials, whereas the gas barrier is inferior. PLA can be processed using standard machinery; and although not yet produced in bulk, large-scale production capacity has been planned by Cargill-Dow Polymers for 2002.

### Lipids

Lipids (e.g. waxes, acetylated glycerides, and fatty acids) and resins (e.g., shellac, and wood resins) have been reported to use as edible coatings. Lipids and resins are non-

polymeric materials. They are usually hydrophobic and act as good moisture barriers, and also often require solvent or high temperature casting. The properties of lipids in biopackaging were thoroughly reviewed (Callegarin *et al.*, 1997). Lipids in a liquid state offer better resistance to gas and vapor transmission than those in a solid state. Many lipids exist in a crystalline form. Individual crystals are highly impervious to gases and water vapor; however, permeates can pass between crystals. Therefore the barrier properties of crystalline lipids are highly dependent on their intercrystalline spacing arrangement (McHugh, 2000).

The best known and oldest coating technique was the application of lipids on specific fruits and vegetables to reduce dehydration, fungi attack, and abrasion during processing and to improve appearance by adding glossiness (Garcia *et al.*, 2000). Acetylated glycerides coatings reduced moisture loss and delayed the onset of lipid oxidation in frozen salmon pieces stored at –23 °C (Stuchell and Krochta, 1995). Waxes are more resistant to moisture transport than most other lipid or non-lipid edible films. Wax coatings are extensively used on fresh produces to extend postharvest shelf life (Baldwin *et al.*, 1997). Shellac coatings are extensively used for candies, shelled nuts and tablets. Fresh produce coating from shellac or mixtures of shellac and waxes, such as carnauba wax, are commercially available (Hagenmaier and Baker, 1995).

### Additives in edible/biodegradable packaging

Besides the main components of edible/biodegradable packaging, some additives are often used to improve the structural, mechanical, or handling properties (Debeaufort

*et al.*, 2000). Plasticizers are usually low molecular weight compounds that impart increased strength and flexibility, but also increase permeability to water vapor and gases. Common plasticizers include water and polyols such glycerol, sorbitol, mannitol, propylene glycol, and polyethylene glycol (Gontard, *et al.*, 1993). Sucrose, sucrose fatty acid esters, as well as acetylated monoglycerides also can be used as plasticizers (Baldwin, 1999).

Emulsifiers, like mono and di-glycerides or lecithins, can be used to reduce the fat globule size and to increase their distribution in emulsified edible films, increasing the overall hydrophobicity of the barrier at the same time. Acids and alkalis are used to improve both the solubilzation of the biopolymers proteins and the homogeneity of the network, and thus, the mechanical properties of the packaging. Surface active substances like sodium lauryl sulfate improve the adhesiveness of edible coating on supports (Debeaufort *et al.,* 2000).

### Composite edible/biodegradable packaging

In general, polysaccharide and protein films give limited resistance to moisture transmission because of the inherent hydrophilicity of such materials. The incorporation of hydrophilic plasticizers sometime is required in order to improve the mechanical properties of polysaccharide and protein based films; however, the addition of hydrophilic plasticizers results in an increase in water vapor permeability (Shaw *et al.*, 2002).

Conversely, hydrophobic lipids are effective moisture barriers, but they have poor mechanical properties. Composite edible/biodegradable packaging, prepared from

incorporation of several compounds or by lamination, have been developed to take advantage of complementary functional properties of these different constitutive materials and to overcome their respective drawbacks.

In general, when natural fibers are mixed with polysaccharides (thermoplastic starch and its blends or cellulose derivatives), the mechanical properties of composites become improved because the chemical similarity of polysaccharides and plant fibers provides good compatibility between them (Curvelo *et al.*, 2001). There have been several studies demonstrated on the use of natural fiber to reinforce biodegradable materials. Dufresene and Vignon (1998) prepared composite materials processed from potato cellulose microfibrils, potato starch as matrix, and glycerol as plasticizer. In the later studies, Dufresne *et al.* (2000) investigated the composite films prepared from the same materials mentioned earlier. They found that incorporation of cellulose microfibrils decreased water sensitivities of resulting films, and mechanical property (tensile strength) was improved with the addition of cellulose mibrofibrils. Recently, cellulosic fibers from *Eucalyptus urograndis* pulp have been used as reinforcement for thermoplastic starch composite to improve its mechanical properties and reduce water sorption (Curvelo *et al.*, 2001). Furthermore, thermoformed trays have been produced from plasticized wheat starch with cellulose fiber composites (Averous *et al.*, 2001). These packaging materials have high stiffness and impact resistance and can be processed on industrial-scale thermoforming equipment.

Garcia *et al.* (2000) prepared starch-based films incorporated with sunflower oil and plasticized with glycerol and sorbitol. The results showed that the addition of lipids to the films produced good barrier to water vapor due to its hydrophobicity.

Plasticization of zein sheets with oleic and linoleic acids resulted in flexible sheets of high clarity, low modulus, high elongation and toughness, but low tensile strength. The water absorption of zein sheets was lowered by the effect of oleic and linoleic acids (Budi-Santosa and Padua, 1999). Lamination of zein sheets with dry oil decreased $O_2$ and $CO_2$ permeability by filling in voids and pinholes in the film structure (Rakotonirainy and Padua, 2001).

### 3.3.5 Method used in the manufacture of edible/biodegradable packaging

The fabrication of edible films and coatings requires the use of at least one component capable of forming a structural matrix with a sufficient cohesiveness. Edible films made with several materials have been optimized in order to account for the complementary functional properties of each component and to minimize their disadvantages.

The film-forming materials can form a continuous structure by setting the interactions between molecules under the action of a chemical or a physical treatment. The film and coating formation involves one of the following processes (Debeaufort, 1998);

- Melting and solidification of solid fats, waxes and resins.

- Simple coacervation where a hydrocolloid dispersed in aqueous solution is precipitated or gelified by the removal of the solvent, by the addition of a non-electrolyte solute in which the polymer is not soluble, by the addition of an electrolyte substance inducing a "salting out" effect, or by the modification of the pH of the solution.

- Complex coacervation, where two hydrocolloid solutions with opposite charges are combined, inducing interactions and the precipitation of the polymer mixture.

- Thermal gelation or coagulation by the heating of the macromolecule solution which involves denaturation, gelification, precipitation, or by a rapid cooling of the hydrocolloid solution that induces a sol-gel transition, for example.

Edible coatings are formed on foods after application by dipping, brushing, spraying, or tumbling. These processes are usually followed by drying steps for aqueous products, or by cooling for lipid based coating (Gontard and Guilbert, 1994).

Stand-alone films have been obtained in the laboratories after laying or spreading a film-forming solution on a support, then drying, and detaching. For industrial processes, techniques used for the manufacture of flexible plastic films can be used to produce edible and biodegradable films. These techniques can be extrusion, or coextrusion for multilayer films, injection, lamination, roll drying and compression molding (Debeaufort, 1998). These processes are based on thermoplastic properties of biopolymers when plastified and heated above their glass transition temperature under low water content conditions. The use of thermoplastic biopolymers has been proposed either to form biodegradable packaging materials for various foods such as edible films or non-food applications, such containers and fast food trays (Guilbert *et al.*, 1997).

The processing techniques used for synthetic polymer processing might be used to produce biodegradable or edible packagings from starch materials. Biodegradable and

edible packaging materials can be produced from extrusion technology (Shogren, 1996; Raiz, 1999; Cha *et al.*, 2001). Compression molding has been used to produce molded biodegradable packaging as well (Hornstein and Landrum, 1997). Recently, acetylated soy protein films have been prepared by compression molding (Foulk and Bunn, 2001).

Films formed at higher compression molding temperatures had higher tensile strength, increased elongation and lower water permeability than the films formed at lower compression molding temperatures. PLA (Polylactic acid) cups can be produced by thermoforming, whereas cornstarch, PHB (Polyhydroxybutyrate) cups have been prepared by injection molding (Petersen *et al.*, 2001). The methods of baking and laminating the starch-based food containers with a hinged lid appearing similar to clamshell containers made of extruded polystyrene (EPS) have been described by Glenn *et al.* (2001). The foam samples laminated with foil, polyvinyl alcohol had the lowest permeance values and had mechanical properties in the same range as those of commercial containers made of EPS or coated paperboard. Ooraikul and Aboagye (1986) developed edible shells consisting of sodium alginate, sodium caseinate, carrageenan, wheat bran and glycerine as plasticizer. Mold surface coating followed by dipping in calcium solution and drying was used to fabricate the edible shells. Compression molding was also used successfully for the purpose.

### 3.3.6 Economy of biodegradable packaging

One of the impediments of using biodegradable packaging is cost. Many of the natural polymer derivatives (cellulose esters and ethers, starch derivatives, etc.) are still produced in batch reactors and thus are more expensive and subject to quality variation.

In contrast, synthetic thermoplastics used in food and drink packaging such as polyethylene (PE), polystyrene (PS) and polyethylene terephthalate (PET) are made in high volume at large production plants, and are relatively inexpensive due to economy of scale and low unit processing costs. PE costs around $0.95 /kg, whereas PS costs twice as much. Because of high quantity, continuous production, product quality and performance are easier to monitor than those of biodegradable packaging materials (Petersen *et al.*, 1999). Table 1.8 shows price comparison between some synthetic polymers and some bio-derived polymers.

**Table 1. 8.   Prices of synthetic polymers and bio-derived polymer (adapted from Petersen *et al.*, 1999)**

| Polymer | Expected Price (CAD/kg)** |
|---|---|
| Cellulose/Cellophane | 2.04-4.08 |
| Cellulose acetate | 4.08-6.80 |
| Starch | 0.68-2.03 |
| Proteins | 1.36-10.87 |
| Polyhydroxyalcanotes (Polyhydroxybutyrate/valerate) | Present: 13.59-16.32 Projected: 4.08-6.80 |
| Polylactate | Projected: 2.72-5.44 |
| Low density polyethylene (LDPE) | 0.86-2.72 |
| Polystyrene | 2.04-2.70 |

** Projected at full scale production

## 4. Conclusion

The waste from food industry poses severe pollution problem to the environment. Much effort has been made to eliminate waste problem. The approaches including 3R's concept (reduce, reuse, and recycle) have been embraced by the industry in order to minimize waste production. New food products are always under development within the food processing industry, in which more efforts should focus on the recovery and use of the solid and liquid wastes produced as by-product. Biodegradable and edible packagings have potential to substitute the non-biodegradable, synthetic plastic packaging in the food industry to a certain degree. However, the cost, performance and processing technology for these biodegradable and edible packaging impede the more extensive use of these packaging materials.

<div align="center">

## Chapter 2

## Materials and Method

</div>

## 2.1 Potato peel

The potato peel was provided by Bassano Growers Ltd. from its pre-peeled potato line in which steam-peeling method is used. The potato peel (PP) was collected and frozen in plastic bags before transporting to the Department of Agricultural Food and Nutritional Science, University of Alberta, Edmonton, Alberta. The PP was stored in a walk-in freezer at the temperature of $-30°C$ until use.

## 2.1.1 Washing method for potato peel

Normally PP is contaminated with dirt and sand. A washing process was developed to remove dirt and gritty particles from the peel. Before the washing process, the ash and moisture contents of PP were analyzed. The PP was thawed at $4°C$ and soaked in tap water for 4 h. Then 400 g of PP was removed from the soaking step and suspended in 3500 mL tap water in a plastic pail. Thereafter a mixture of PP and water was agitated with a magnetic stirrer (IKA-COMBIMAG RET, Model RET S2, Janke & Kunkel Co., Germany) (Figure 2.1). The speed of the magnetic stirrer was set at 1100 rpm. The PP samples were collected at 0, 30, 60, 90 and 120 min, respectively, and the ash content determined.

PP collected at each washing time mentioned earlier was dried in a hot air dryer (Harvest Maid Preserver, Food dehydrator, Model FD-101, Alternative Pioneering Systems, MN) at $105°C$ for 6 h to a moisture content of about 5%. Thereafter PP from

each washing time was ground in a coffee grinder (Braun, Model KSM2, Braun Canada, Mississauga, ON) and sifted through 20 mesh screen. The ground PP that passed through 20 mesh screen was mixed with mashed potato at 10% (w/w) level and baked to produce edible shells using the method described in section 2.4.2. The sensory test to determine the efficiency of washing method test was also conducted. The sensory method performed was described in details in section 2.7.1.

## 2.1.2 Preparation of potato peel

After the washing steps, the PP was dried in a hot air dryer (Harvest Maid Preserver, Food dehydrator, Model FD-101, Alternative Pioneering Systems, MN) at 105 °C for 6 h to a moisture content of about 5%. Initially, the dried PP was ground and sifted through 20 mesh screen. The preliminary sensory evaluation determined the grittiness and coarse texture of the samples. The results indicated that the dried PP was too coarse. Therefore, the PP were further ground in a coffee grinder (Braun, Model KSM2, Braun Canada, Mississauga, ON), and sifted through a series of sieves having apertures of 595, 420 and 200 μm which are 30, 40 and 80 mesh screens, respectively. Samples finer than 200 μm were not used because of the probability that soil and sand particles were present. Ground peel was stored at 4°C before chemical analyses and used in the formulation of edible shells.
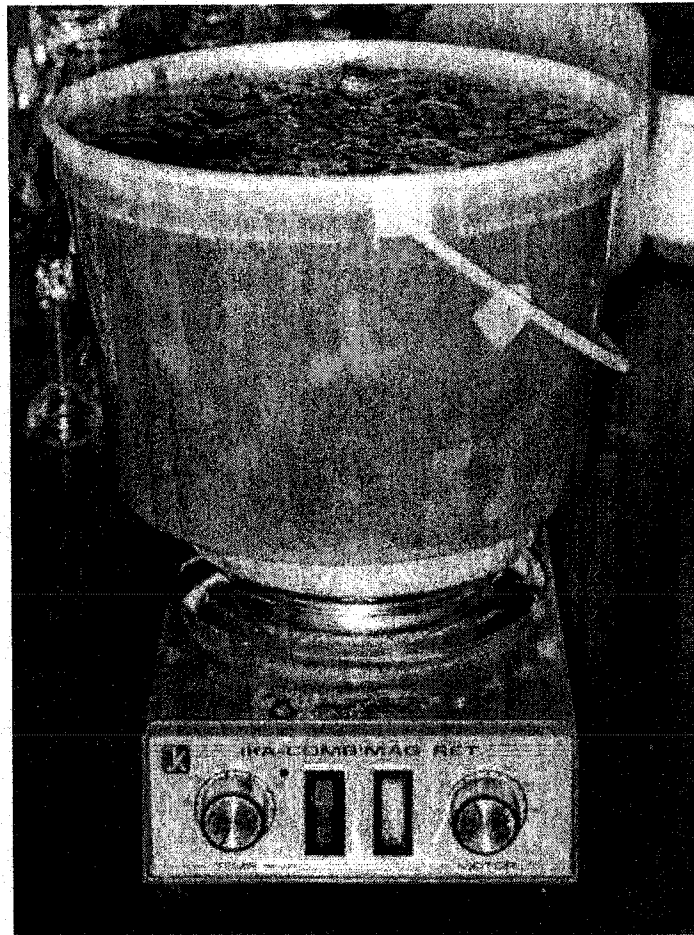
**Figure 2.1. Circulating water bath used for washing potato peel.**

## 2.2 Chemical composition

### 2.2.1 Moisture, ash, protein, and crude fat

Triplicate analyses of moisture, ash, protein (N x 6.25) and crude fat of the PP were conducted according to AOAC (1995).

### 2.2.2 Total starch

Total starch content of PP was determined in duplicate by using an enzymatic assay kit and procedure outlined by Megazyme (Megazyme International Ireland Ltd., Wicklow, Ireland). The method used for total starch determination followed AOAC method 996.11 and AACC method 76.13. The PP samples were washed with 80% ethanol (v/v) prior to analysis. The samples were digested by thermostable $\alpha$-amylase at 100°C and then hydrolyzed to glucose by amyloglycosidase at 50°C. The entire contents obtained were diluted to 10 mL with distilled water then centrifuged. The aliquots obtained were subjected to glucose measurement using spectrophotometer at 510 nm wave length. The concentrations of glucose were calculated to obtain the starch content. The starch content was calculated as follows:

$$\text{Starch }(\%) = A \times F \times 1000 \times \frac{1}{1000} \times \frac{100}{W} \times \frac{162}{180}$$

$$= A \times \frac{F}{W} \times 90$$

Where:

A = Absorbance (reaction) read against the reagent blank.

$$F = \frac{100 \text{ (μg of glucose)}}{\text{Absorbance for μg of glucose}}$$

1000 = Volume correction (0.1 mL taken from 100 mL)

$\frac{1}{1000}$ = Conversion from micrograms to milligrams.

$\frac{100}{W}$ = Factor to express "starch" as a percentage of sample weight.

W = The weight in milligrams of the sample analyzed.

$\frac{162}{180}$ = Adjustment from free glucose to anhydro glucose

(as occurs in starch).

## 2.2.3 Soluble and insoluble dietary fiber

Soluble and insoluble dietary fiber contents of PP were determined in duplicates by using an enzymatic assay kit and procedure outlined by Megazyme (Megazyme International Ireland Ltd., Wicklow, Ireland). The method used to determine soluble and insoluble dietary fiber was the modification of AACC method 32-05 and 32-21. After defatted in fat determination, the 1 g PP was cooked at 100°C with thermostable α-amylase then incubated at 60°C with protease and amyloglucosidase. The mixture was filtered, thereafter the residues obtained from filtration were washed with 70°C distilled water, dried at 103°C in an oven, and weighed. One duplicate was analyzed for protein and the other for ash.

The solution of filtrate from insoluble dietary fiber determination mentioned above was mixed with four volumes of 95% ethanol (v/v) to precipitate soluble dietary fiber (SDF) at room temperature for 2 h. The residue was filtered, washed with 78% ethanol (v/v), 95% ethanol (v/v), and acetone consecutively, then dried at 103°C in an oven, and weighed. One residue was analyzed for protein and the other residue was analyzed for ash. Two blank samples were conducted along with samples in both IDF and SDF determination. Insoluble and soluble dietary fibers in PP were calculated as follows:

$$\text{Dietary fiber (\%)} = \frac{\dfrac{(R_1 + R_2)}{2} - p - A - B}{\dfrac{m_1 + m_2}{2}} \times 100$$

Where:

$R_1$ = residue weight 1 from $m_1$; $R_2$ = residue weight 1 from $m_2$;

$m_1$ = sample weight 1; $m_2$ = sample weight 2;

A = ash weight from $R_1$; p = protein weight from $R_2$ ; and

B = Blank

$$= \frac{BR_1 + BR_2}{2} - BP - BA$$

where:

BR = blank residue;        BP = blank protein from $BR_1$;

BA = blank ash from $BR_2$.

## 2.2.4 Glycoalkaloid determination.

Matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS) adapted from the procedures developed by Abell and Sporns (1996) and Driedger and Sporns (1999a) was used to quantify individual glycoalkaloid in PP.

**Apparatus**

a) MALDI-TOF MS. – a Proflex III instrument with a linear flight tube (Bruker Analytical Systems Inc., Bellerica, MA).

b) Benchtop centrifuge. – Beckman Microfuge II (Beckman Instruments, Fullerton, CA).

c) Orbital shaker. - Junior orbital shaker (Lab-Line Instruments, Melrose Park, NJ).

d) Coffee grinder. – household type (Braun, Model KSM2, Braun Canada, Mississauga, ON)

**Reagents**

a) HPLC grade methanol and acetone, and deionized water.

b) 2,4,6-trihydroxyacetophenone- Aldrich Chemical Co. (Milwaukee, WI).

c) $\alpha$-Chaconine. – Sigma Chemical Co. (St. Louis, MO).

d) $\alpha$-Solanine. – Sigma Chemical Co. (St. Louis, MO).

e) $\alpha$-Tomatine. – Sigma Chemical Co. (St. Louis, MO).

f) Extraction solvent. – Methanol-water (1:1, v/v) containing 10 $\mu$g/mL $\alpha$-tomatine as an internal standard.

g) Standard glycoalkaloid solutions. – 0, 5.0, 10.0, 20.0, 30.0 and 40.0 µg/mL α-chaconine and α-solanine in approximately equal proportions. Standards were prepared in the extraction solvent mentioned earlier, which was methanol-water (1:1, v/v) containing ca. 10 mg/mL α-tomatine as an internal standard.

h) MALDI-TOF MS matrix solution. - 200 µL of saturated 2,4,6-trihydroxyacetophenone solution was prepared in 1 mL (v/v) acetone and centrifuge at 10,000 rpm for 20 s. The supernatant was used for preparing matrix crystals.

## Sample Extraction

Six samples were extracted in duplicate with the extraction solvents containing standard glycoalkaloid solutions. 200 ± 2 mg ground PP was weighed and suspended in 10 mL extraction solvent containing standard glycoalkaloid solutions at the concentrations of 0, 5.0, 10.0, 20.0, 30.0 and 40.0 µg/mL α-chaconine and α-solanine and 10 µg/mL α-tomatine as an internal standard. The samples were shaken for 3 h at 200 rpm on an orbital shaker. One mL of each sample extract was transferred to a microcentrifuge tube and centrifuged at 3000 rpm for 10 min. The supernatants of the samples were used for MALDI-MS analysis.

## MALDI –TOF MS Analysis

a)      **Probe preparation**: MALDI-TOF MS matrix solution (0.5 µL) was deposited onto the stainless steel probe and allowed to dry. 0.6 µL PP extract was placed on top of

trihydroxyacetophenone crystals and allowed to dry for 10 min. The probe was rinsed with deionized water for about 3 s and allowed to air dry.

b)  **Collection of spectra**: The analytes were ionized by a nitrogen laser pulse (337nm) and accelerated under 20 kV with time-delayed extraction before entering the time-of-flight mass spectrometer. Spectra were collected by firing the laser stepwise across the entire spot at an average of 100 shots from each spot. The average peak intensities were compared with the α-tomatine as an internal standard of each extract. If the sodium and potassium adducts were present, the intensity of the sodium and potassium adduct peaks were added to the intensity of the protonated peak. It is important to include all of these peaks in quantitative analysis based on observances of variation between response of these adducts amongst spot replicates, but not as much quantitative variation of their sum as a representation of the glycoalkaloid concentration.

### Quantification of α-chaconine and α-solanine

a)  Six samples of potato peel were extracted and "spiked" by using the extraction solutions containing both α-chaconine and α-solanine at the concentrations of 0, 5.0, 10.0, 30.0, and 40.0 μg/mL and 10 μg/mL α-tomatine as an internal standard. The MALDI-MS responses of the glycoalkaloids were expressed as the percentage of α-chaconine and α-solanine peak height intensities relative to the internal standard's peak height intensity. The MALDI-MS response obtained was plotted against the "spiked" α-chaconine and α-solanine concentration. The second-order polynomial regression analysis was applied to the data plotted by using Microsoft Excel 2000, (Microsoft, Redmond, VA).

b)      The concentration of glycoalkaloid in the extract was determined by extrapolating the second-order polynomial regression curve as previously described to the x axis. The glycoalkaloid concentration in the extract was obtained from the point where the second-order polynomial touched the x axis. The concentration of glycoalkaloid in the ground PP was calculated as follows:

$$\frac{\mu g \text{ of Glycoalkaloid}}{g \text{ of potato peel}} = (C \times V)/W$$

where C is the glycoalkaloid concentration in the extract ($\mu$g/mL), V is the volume of solvent used to extract the sample (mL), and W is the weight of ground PP samples (g). Glycoalkaloid concentration was calculated based on the moisture content of PP at 5%.

## 2.2.5 Hydration capacity of PP

AACC method 56-20 (1983) was modified by adding 10 mL deionized water to 0.5g triplicate samples. After 10 min rest period, the 15 mL plastic screw-capped tubes containing the samples were centrifuged for 20 min at 4000 x g in a centrifuge (MSE, England). Water was removed by decanting the supernatant and inverting the tube to drain. The residue was weighed and the water hydration capacity was calculated as g water retained/g peel dry matter.

## 2.3 Formulation of edible shell

Based on previous experiences in the formulation of baked edible shells, mashed potato was chosen as the basic ingredient for the baked shells. Preliminary work was done to optimize the amount of PP in the formulation. The amounts of PP added in the formulations were varied at 10%, 20% and 30% levels, and the resulting edible shells were investigated for baking results. After preliminary trials for the levels of the PP incorporation, 10% PP addition to mashed potatoes was chosen and the shells produced for the preliminary sensory evaluation.

Based on the preliminary sensory evaluation results which indicated the lack of shell cohesiveness, gums, and monoglyceride, as plasticizers, were incorporated to the formula in order to improve the quality of the edible shells.

The formulae used for baked edible shells are given in Table 2.1. The peel was mixed with mashed potato, potato starch (Casco, Bestfoods Canada, Inc), carrageenan (CECA, France), pectin (Frank E. Dempsey & Sons Ltd., Canada), and monoglyceride (Crest Foods Inc., IL) to produce edible shells by baking. The formulae were calculated to yield a 1.0 kg batch. To prepare mashed potato, potato tubers (Bassano Growers Ltd., Alberta) were cleaned and cut before steam cooking. After steaming for 30 min, cooked potato was mashed by a kitchen mixer (KitchenAid, Model K45SS, KitchenAid USA). In each formula, mashed potato was incorporated with potato peel at 2.5, 5, and 10% (w/w) levels. The ingredients were mixed in the kitchen mixer. The mashed potato was blended with the PP at low speed while gradually adding the PP. The other ingredients were then added to the mixture. The amount of water used in the formulae varied and was increased as the level of potato peel increased.

**Table 2.1. Formulation for edible shells**

| Ingredients (g) | % Potato Peel | | |
|---|---|---|---|
| | 2.5% | 5% | 10% |
| Mashed potato | 900.00 | 875.00 | 825.00 |
| Potato peel | 25.00 | 50.00 | 100.00 |
| Carrageenan | 25.00 | 25.00 | 25.00 |
| Pectin | 25.00 | 25.00 | 25.00 |
| Monoglyceride | 0.01 | 0.01 | 0.01 |
| Potato Starch | 25.00 | 25.00 | 25.00 |
| Total | 1000.00 | 1000.00 | 1000.00 |

## 2.4 Baking process for edible shell

### 2.4.1 Baking mold

A photograph of the baking mold is shown in Figure 2.2. The male and female mold sections were formed separately and were connected with a hinge. The molds are made of heat conducting aluminum. Heating elements are imbedded in each section. Temperature was adjusted separately for the male and female molds by means of two variable electric transformers, and the temperature was measured by thermocouples attached to each mold section. The two mold sections were preheated and maintained at 130°C prior to the introduction of the mixture to minimize the baking time.

### 2.4.2 Processing of edible shells

A 22 g portion of the potato mixtures was placed into the female mold. The male mold was pressed onto the female mold to form an oblong edible shell. The mixture was

potato shell, with the dimension of 9.5 x 6 x 3 cm (length x width x depth). Each edible shell was baked for 5 min resulting in a final product moisture content ranging from 2.5 – 4%.

## 2.5 Physical properties of edible shells

The processed edible shells were stored in polyethylene bag at room temperature for 24 h before physical evaluation.

### 2.5.1 Color

Color was measured with a HunterLab colorimeter (Hunter Associates Laboratory Inc., USA). The whole edible shells were measured for the color of the outside surface. Hunter L*, a* and b* values were measured twice after rotating the edible shells 90°. Two samples from each treatment were measured. In case of stuffed potato and control made form scooped-out baked potatoes, mashed potatoes were removed before measuring the color.

### 2.5.2 Weight and thickness

Edible shells were weighed in triplicate by using a top loading digital balance with an accuracy of two decimal places. Thickness of three edible shells from each treatment were measured, using a vernier caliper at five random locations.
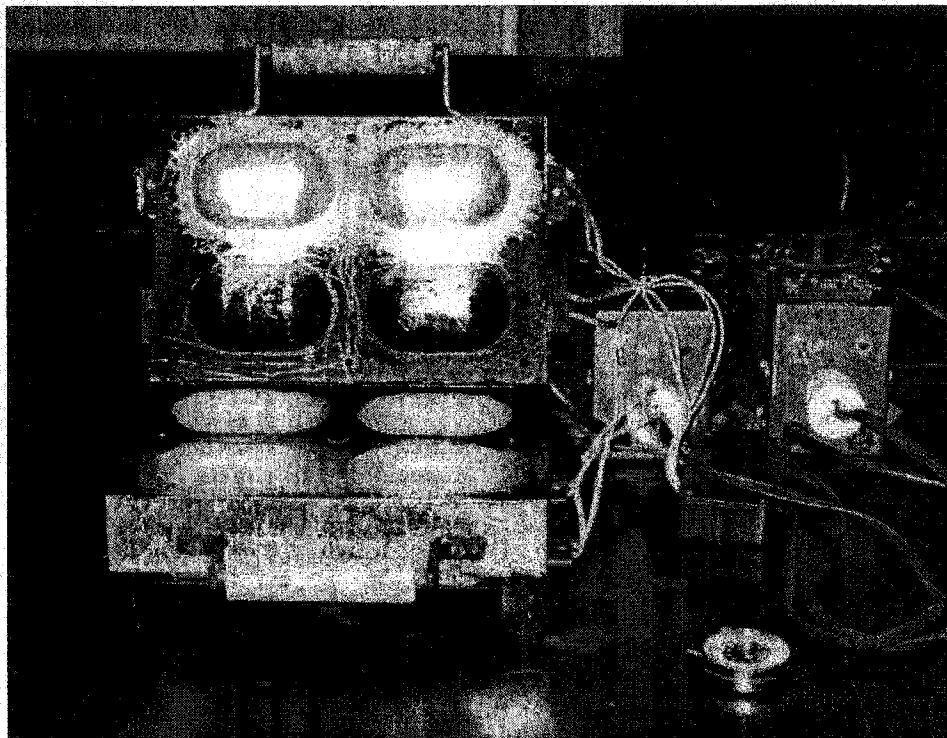
**Figure 2.2. Baking mold.**

### 2.5.3 Texture

Texture of the edible shells was determined using Instron Texture testing equipment (Model 4201, MA, USA). The whole empty edible shells were placed and compressed (punctured) by the 8.5 cm compression anvil and 5 kg load cell. The edible shell was placed upside down and punctured from outside to inside. Three samples from each formula were tested, and the maximum forces required to puncture were averaged and reported. For texture determination of stuffed shells, the mashed potato was removed from the stuffed shells before testing.

### 2.5.4 Water absorption

Five edible shells from each formulation were evaluated for water absorption. After weighing, the edible shells were filled with 15 mL of water for 3 min. The edible shells were emptied then weighed again to determine the percentage of water absorption as follows:

$$\% \text{ Water absorption} = \frac{(W_2 - W_1)}{W_1} \times 100$$

Where; $W_1$ = weight of edible shells before being filled with water

$W_2$ = weight of edible shells after the remaining water was poured out.

### 2.5.5 Texture of edible shells after absorbing water

Texture of edible shells after absorbing water was evaluated by using the same method as previously explained in the test for empty shells.

## 2.6 Development of stuffed potatoes

The filling for edible shells was prepared. The potato tubers were peeled and cut before steam cooking. After being cooked for 30 min, the potato was mashed with 0.01% salt and 0.01% butter (w/w). The edible shells were filled with mashed potato and stored in sealed polyethylene bags. Then the filled shells were frozen in a walk-in freezer at -30°C. The stuffed potatoes were stored in the freezer prior to the evaluations.

## 2.7 Sensory evaluation of edible shell

Sensory evaluations were performed in five tests: 1) Sensory test to determine the efficiency of washing method; 2) Preliminary Test – an untrained sensory panel provided a preliminary acceptability of edible shells compared to the shells filled with mashed potato; 3) Test I –untrained panelists evaluated filled edible shells containing three concentration of potato peels (2.5%, 5%, and 10% PP); 4) Test II- The untrained panelists scored the edible shells that had been reheated by two different methods, oven reheating and microwave reheating; 5) Consumer evaluation –the edible shells whose formulation and reheating methods had been found acceptable in previous tests were evaluated for consumer's acceptability in comparison with the control made from scooped-out baked potatoes refilled with mashed potatoes. All sensory evaluations performed were described in details as follows:

### 2.7.1 Sensory test to determine the efficiency of washing method

Sensory test was conducted to determine the grittiness which indicated the efficiency of washing method. Ten untrained panelists consisted of 5 graduate students (3 females, 2 males), 2 staff (males) and 3 visiting researchers (2 females, 1 male) in the Department of Agricultural Food and Nutritional Science, University of Alberta were recruited through personal communication. The samples were cut in half and assigned three-digit random codes. The panelists chewed the samples to detect sand and dirt particles. The scores were reported as "detected" or "not detected".

### 2.7.2 Preliminary sensory evaluation of empty edible shells compared to the shells filled with mashed potato

#### 2.7.2.1 Experimental design

In order to explore acceptability of the edible shells, a preliminary sensory evaluation was conducted. The edible shells were baked 3 days before the test. Cooled empty edible shells were sealed in polyethylene bags and stored at room temperature. The empty edible shells used in this test were the 10% PP formula made with dried peel that was milled to pass through a 20-mesh sieve. The mashed potato for filling was prepared by cooking peeled, sliced potato for 30 min in a steam cooker. Cooked potato was then mashed with a household mixer (KitchenAid, Model K45SS, KitchenAid USA). The empty edible shells were filled with mashed potato and thereafter frozen in a walk-in freezer at the temperature of –30°C for 48 h. Before the sensory evaluation, the frozen stuffed potatoes were transferred to a refrigerator for 6 h to slowly thaw the product. The stuffed potatoes were reheated for 3 min in a microwave oven (Sumsung, MW 558w) before serving to the panelists. Samples were assigned three-digit random codes. The whole empty shells were evaluated by panelists first followed by the stuffed shells.

#### 2.7.2.2 Sensory method

Acceptance testing, using a nine-point hedonic scale (1, dislike extremely; 9, liked extremely), was used for the sensory evaluation of empty edible shells and stuffed edible shells. The panelists evaluated both products for appearance, color, texture, flavor, and overall acceptability. These sensory attributes were evaluated on a nine-point hedonic

scale, except the brightness of the shells in which a five-point rating scale (1- light, 3- just about right, 5- dark) was used.

### 2.7.2.3 Panelists

Approval for the project was granted by the Human Ethics Research Board, Faculty of Agriculture, Forestry and Home Economics, University of Alberta. Potential panelists were recruited through advertisement posters and personal communication. The potential panelists were provided with information sheet, and consent forms. Panelists were selected based on their interest, available time, and lack of allergies to food ingredients used in the study. The 21 female and 14 male panelists recruited were University of Alberta employees and students. No sensory training was provided prior to the evaluation session. Panelists were asked to rinse their mouth with water before testing each sample. Sensory analysis was conducted in a sensory evaluation laboratory area with partitioned booths illuminated by fluorescent lighting. Test I, Test II and the consumer evaluation were also conducted at the sensory evaluation laboratory area.

### 2.7.3 Test I

The frozen stuffed potatoes were thawed at 4°C for 6 hr before heating with microwave oven for 3 min. The samples were assigned three digits random codes and served to the panelists randomly. Panelists were given room temperature water to cleanse their palates before the presentation of samples from each formulation. The sensory evaluation panel consisted of 8 graduate students (6 females, 2 males) and 2 staff (males) in the Department of Agricultural, Food and Nutritional Science, University of Alberta.

The panelists were recruited through personal communication. The panelists were asked to rate the color, hardness, cohesiveness, grittiness, texture, flavor, and overall acceptability. The five-point rating scales used for color evaluation were: 1- light, 3- just about right, 5- dark. The seven-point rating scales used were: hardness: 1 = soft, 7 = hard; cohesiveness: 1 = loose, 7 = cohesive; grittiness: 1= none, 7 = much. A nine-point hedonic scale (1, dislike extremely; 9, liked extremely) was used for texture, flavor and overall acceptability. The terms for each sensory attribute were explained to the panelists as follows: "hardness" is the force required to bite through the sample; "cohesiveness" is the amount of sample that deforms rather than ruptures; "grittiness" is the amount of small, hard particles perceived between teeth during chewing.

### 2.7.4 Test II

Microwave-oven reheated products were prepared as described in Test I. For the regular-oven reheated products, the household oven was preheated to 350°F (175°C). The stuffed potatoes were placed in the oven and baked for 35 min. The samples were assigned three random digits codes and served randomly to the panelists. Ten untrained panelists consisted of 8 graduate students (4 females, 4 males) and 2 staff (males) in the Department of Agricultural, Food and Nutritional Science, University of Alberta were recruited by personal communication. The Panelists were asked to rate color, hardness, cohesiveness, texture, flavor, and overall acceptability of the samples on the same rating scales used in Test I. A seven-point rating scale (1 = crisp, 7 = not crisp) was used for crispness of the samples. The terms of each sensory attribute were explained as in Test I.

The term for crispness was also described as the noise and force with which the sample breaks or fractures.

### 2.7.5 Consumer evaluation

Sensory properties of the product containing 2.5% PP were evaluated in comparison with a control made from scooped-out baked potato shells refilled with mashed potatoes. The control was prepared in the similar manner as commercial stuffed baked potatoes but without addition of toppings. Both samples and controls were reheated with the regular oven as recommended by the producer for the stuffed baked potatoes. They were stored in the freezer for 21 d before evaluation. The samples and controls were reheated in the oven at 350°F (175°C) for 35 min before serving. The products and controls identified by three random digits codes were offered to the panelists. Room-temperature water was provided for cleansing the palates before the presentation of each sample.

The recruitment of panelists was done in the same manner as for in the panelists of the preliminary test. An untrained 56-member panel evaluated the appearance, color, texture, flavor, and overall acceptability of edible shells containing 2.5% PP compared to the control on a 9-point hedonic scale (9= like extremely; 1 = dislike extremely). A five-point rating scale (1- light, 3- just about right, 5- dark) was used for brightness.

## 2.8 Statistical analysis

All the experimental data and sensory data obtained were analyzed statistically with the analysis of variance for statistical significance (p = 0.05) using Tukey's Test (SAS Program Windows Version 8. 2: SAS Institute Inc., Cary, NC, USA). Sensory data obtained in this study were from interval scales, and the data from interval scales are analyzed using parametric statistical tests (Lermond, 1977). Analysis of Variance (ANOVA) is the most common test for interval sensory data, and Tukey's test is multiple comparison of means test to identify samples that differ from each other, once the presence of statistical difference has been confirmed using the Analysis of Variance (Watts *et al.*, 1989).

## Chapter 3

## Results and Discussion

### 3.1 Recovery and cleaning of potato peels

A photograph of PP from the Bassano Growers Ltd is shown in Figure 3.1. The PP had a high moisture content at 82.59%. The PP obtained from the company was highly contaminated with dirt and sand as indicated by the high ash content (13.23%) (Table 3.1). The sensory results and ash content revealed that soaking step did not significantly remove sand and dirt from the PP. It was observed that there were dirt and sand particles precipitated after the PP was removed. Washing PP for 30 min did not reduce the particles significantly as compared to soaking alone. In the washing study, the ash content was decreased significantly as washing time increased to 60 min (Table 3.1). However, the sensory results indicated that seven out of ten panelists detected the grittiness of the samples. As the washing time increased to 90 and 120 min a greater amount of sand and dirt particle were released, as the ash contents were decreased. The washing time of 90 min was, nonetheless, found to be inadequate to clean the PP because three panelists still perceived the grittiness of the samples.

Generally, potato peels obtained from the steam peeling process contain about 6.01% ash on a dry weight basis (Camire, *et al.*, 1997; Toma, *et al.*, 1979). In those studies, the PP was not thoroughly washed. In the present study, it was found that soaking followed by washing the PP for 120 min decreased the amount of dirt and sand particles significantly to an ash content of 5.26% on a dry weight basis. The sensory results of the product also indicated that only one panelist perceived the grittiness of the samples.

Consequently, the washing time of 120 min was used to clean the PP throughout the study.



**Figure 3.1.  Thawed potato peel.**

**Table 3.1.** Ash content and grittiness of potato peel soaked and washed for different lengths of time

| Washing Time (min.) | Ash Content* | Sensory results (Number of panelists who could detect the grittiness) |
|---|---|---|
| Thawed potato peel | $13.23 \pm 1.55$ [a] | 10/10 |
| After soaked | $13.11 \pm 1.55$ [a] | 10/10 |
| 30 | $11.96 \pm 1.37$ [a] | 10/10 |
| 60 | $9.17 \pm 1.28$ [b] | 7/10 |
| 90 | $5.60 \pm 0.11$ [c] | 3/10 |
| 120 | $5.26 \pm 0.56$ [c] | 1/10 |

*Results are averages of triplicates
a, b, c Mean scores in the same column not sharing the same superscript are significantly different ($p < 0.05$).

## 3.2 Chemical analysis of potato peels

Proximate composition of PP is given in Table 3.2. A considerable amount of sand and dirt particles was removed from the PP during the washing process, which greatly lowered its ash content. This result is lower than the findings of Camire *et al.* (1997) and Toma *et al.* (1979). Starch content in washed PP was low when compared with the results reported by Camire *et al.* (1997). This may be due to the substantial removal of the starch from the PP during washing steps. Slightly lower crude fat obtained in the PP is in good agreement and the protein content agrees closely with the findings of Camire *et al.* (1997).

It has been reported that the PP fibers are primarily insoluble (Camire and Flint, 1991). The PP contained 56.61% insoluble dietary fiber and 4.48% soluble dietary fiber

(Table 3.2). The dietary fiber results are in agreement with those of earlier researchers

(Camire *et al.*, 1997).

**Table 3.2. Proximate composition of dried potato peels\***

| Ash\*\* | 5.26% |
|---|---|
| Crude Fat\*\* | 0.99% |
| Protein ($N$ x 6.25)\*\* | 18.97% |
| Moisture\*\* | 4.84% |
| Total dietary fiber \*\*\* <br>    - Insoluble dietary fiber  56.61% <br>    - Soluble dietary fiber     4.48% | 61.09% |
| Total starch\*\*\* | 15.70% |

\* % dry basis.
\*\* Results are average of triplicates
\*\*\* Results are average of duplicates

The hydration capacity (Table 3.3) coincided with previous results reported by

Toma *et al.* (1979).

**Table 3.3 Hydration capacity of potato peels**

| Hydration capacity | 12.56\*\* |
|---|---|

\*\* Average of triplicate measurements; grams of water per gram of PP.

Glycoalkaloids are difficult to analyze because of their heterogeneity and lack of a

useful chromophore to use for colorimeter analysis (Driedger and Sporns, 1999a).

Analysis of glycoalkaloids in potato material by using HPLC techniques have been

reported (Zhao *et al.*, 1994; Abell and Sporns, 1996; Sotelo and Serrano, 2000). The

HPLC methods rely on UV detection in the 200-208 nm region so that extensive sample

clean-up is required to remove interfering compounds (Driedger and Sporns, 1999b).

Immunoassays are rapid, and simple methods to quantify total glycoalkaloids and now

are commercially available, but cannot distinguish individual glycoalkaloids (Friedman *et al.*, 1998).

Matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF) has been used successfully to quantify individual glycoalkaloids in potato materials (Abell and Sporns, 1996; Driedger and Sporns, 1999a; Driedger and Sporns, 1999b). The methods used in this study were an adaptation of those procedures and used to determine the glycoalkaloid concentration of the PP.

Figure 3.2 illustrates the MALDI mass spectrum of potato peel containing 10 µg/mL tomatine as an internal standard, without $\alpha$-chaconine and $\alpha$-solanine "spiked" added in the extraction solution. Upon analysis of PP samples, potassium adduct peaks were observed as peaks 39 mass units higher than the actual molecular weights of each glycoalkaloid, and sodium adduct peaks were also appeared as peak 23 mass units higher than the molecular weight of $\alpha$-tomatine (Figure 3.2). The adduct peaks were also observed in the studies of Abell and Sporns (1996) and Driedger and Sporns (1999a and 1999b). This may be due to the fact that few or no fragments are produced during ionization in MALDI-MS because ionization process is very gentle (Sporns and Wang, 1998). As a result, spectra of glycoalkaloids in MALDI-MS could be represented as protonated peak (glycoalkaliod + $H^+$), sodium adduct peak (glycoalkaliod + $Na^+$) and potassium adduct peak (glycoalkaliod + $K^+$). In the quantitative glycoalkaloid analysis, the calculations were carried out on the sum of protonated peak height intensities and adduct peak height intensities (Abell and Sporns, 1996; Driedger and Sporns, 1999a, 1999b). In the present study, the peak height intensities of $\alpha$-chaconine and $\alpha$-solanine as well as $\alpha$-tomatine were calculated in the similar way.

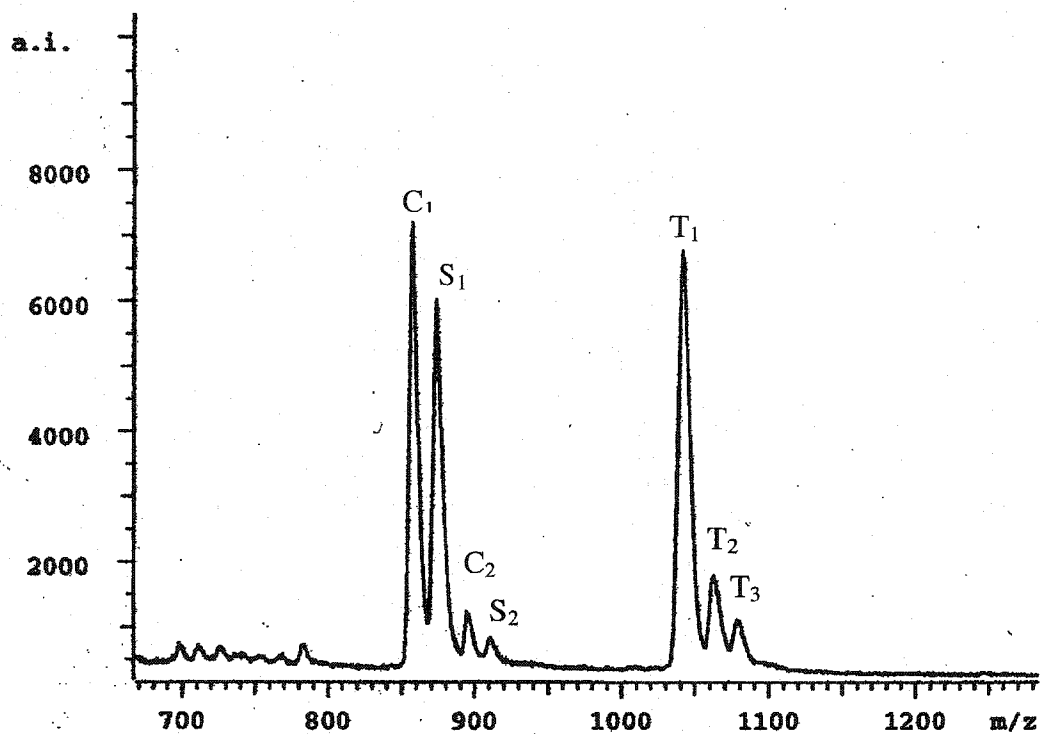**Figure 3.2. MALDI-TOF mass spectra of potato peel with α-tomatine as an internal standard without α-chaconine and α-solanine standard solutions added to extraction solvent. $C_1$, α-chaconine + $H^+$ (MW 852); $S_1$, α-solanine + $H^+$ (MW 869); $C_2$, α-chaconine + $K^+$ (MW 891); $S_2$, α-solanine + $K^+$ (MW 908); $T_1$, α-tomatine + $H^+$ (MW 1035); $T_2$, α-tomatine + $Na^+$ (MW 1058); $T_3$, α-tomatine + $K^+$ (MW 1073).**

The second-order polynomial regression curve above zero was fitted to the relationship between MALDI-MS response and glycoalkaloid concentration (Figure 3.3 and 3.4). This is in agreement with the findings reported by Abell and Sporns (1996) and Driedger and Sporns (1999a). The MALDI-MS responses as a percentage of the internal standard response correlated well with the "spiked" standard concentration, with coefficient of correlation values at 0.96 (Figure 3.3 and 3.4).

Concentrations of α-chaconine and α-solanine per g of the PP are given in Table 3.4. These findings are higher than those reported for French fry by-products PP by Zhao *et al.* (1994), but the α-chaconine and α-solanine ratios are close to those reported in that study. The different findings for the concentration of individual glycoalkaloids may be due to the difference in methods used and the variety of potatoes or the harvesting and storing conditions of the potatoes. Friedman and Dao (1992) reported that the total glycoalkaloids of commercial baked potato skins ranged from 3.1 to 20.3 mg/100g due to the difference in potato varieties. The PP may be incorporated to the products at a level of 11g/100g of final product without exceeding the recommended limit of 20mg/100g, but this level may affect the sensory and physical properties of the final products.

**Table 3.4. Chaconine and solanine in potato peels determined by MALDI - MS***

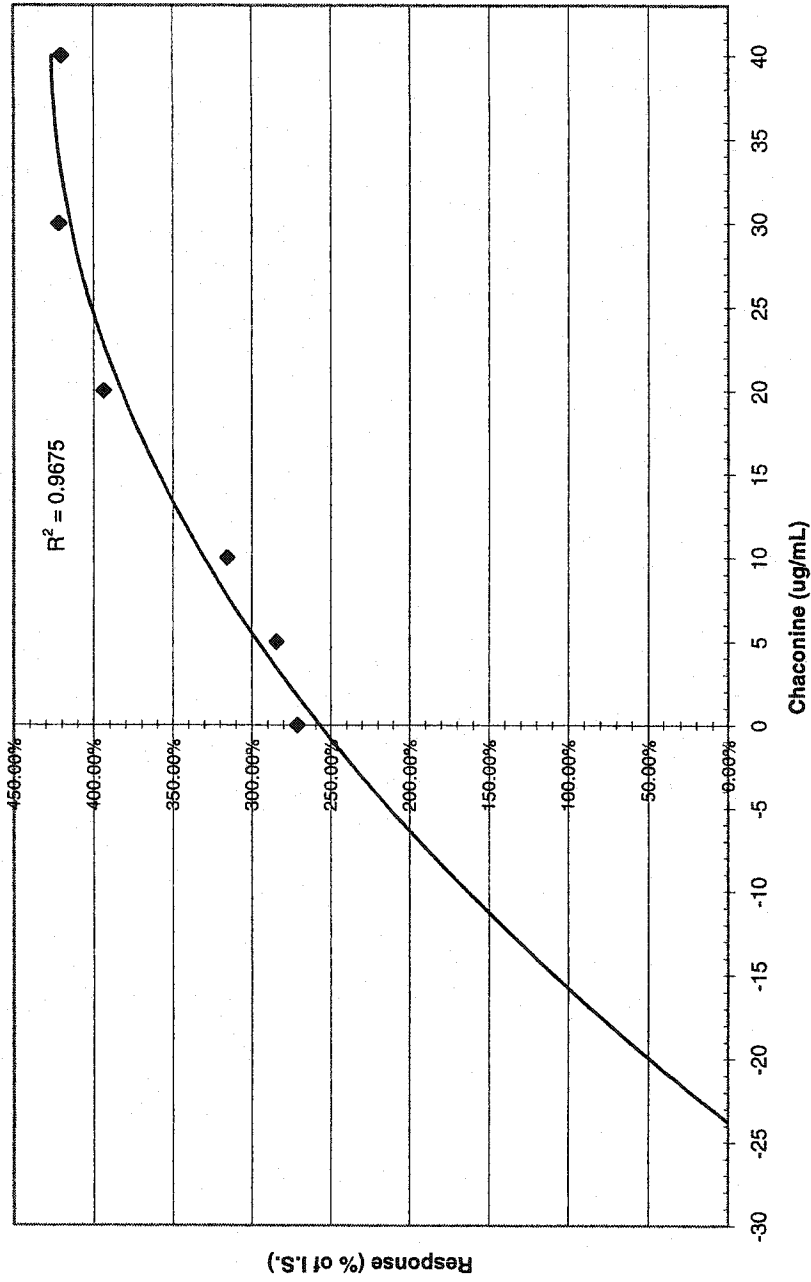| α-chaconine (μg/g) | α-solanine (μg/g) | Total Glycoalkaloids (μg/g) |
|---|---|---|
| 1.18 | 0.62 | 1.80 |

* dry weight basis

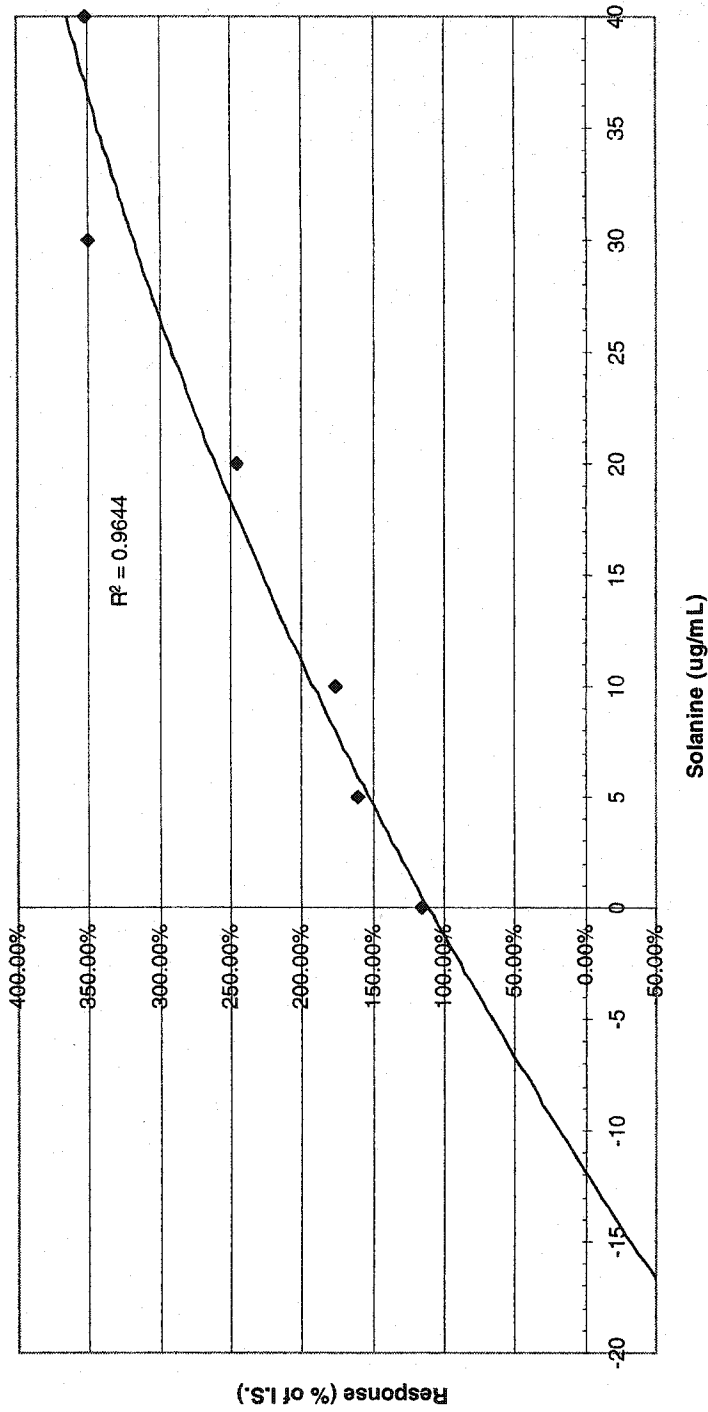**Figure 3.3. Second-order polynomial curve for α-chaconine using MALDI-TOF MS.**

Figure 3.4. Second-order polynomial curve for α-solanine using MALDI-TOF MS.

### 3.3 Production of edible shell

#### 3.3.1 Formulation and baking

In order to optimize the formulations, the PP was used to replace part of mashed potato at 10%, 20% and 30% in the recipe. In mixing trials, each formula contained only mashed potato and the PP. It has been observed that as the level of PP substituted in the edible shell formula were increased, the addition of water required to produce dough was necessitated for 20% and 30% levels. This may be due to the fact that the hydration capacity of the PP is high at 12.56 g of water per gram of PP. As a result, PP may absorb water from the mashed potato used. It has been reported that moisture contents of the raw dough of dietary fiber enriched products were adjusted on manufacture, accounting for different water absorption levels of fiber used (Tudorica *et al.*, 2002; Vratanina and Zabik, 1978).

The time and temperature are important parameters for the baking process of the edible shells, thus these two parameters were investigated by trial testing. It was found that if temperatures of the female and male molds were greater than 145°C, it would result in burnt shells. Temperature setting of the molds lower than 120°C resulted in longer baking times (more than 7 min). Subsequently, the female and male mold sections were heated and maintained at 130°C for 5 min baking process. These time and temperature were found to be most suitable for the baking process.

Once a 22 g dough was placed and enclosed in the mold, it was observed that the 10 % PP dough became fluid enough to evenly disperse through the mold, whereas the 20% and 30% PP dough were difficult to disperse and did not form perfect shapes. Figure 3.5 illustrates the appearance of the edible shells baked from blends of mashed
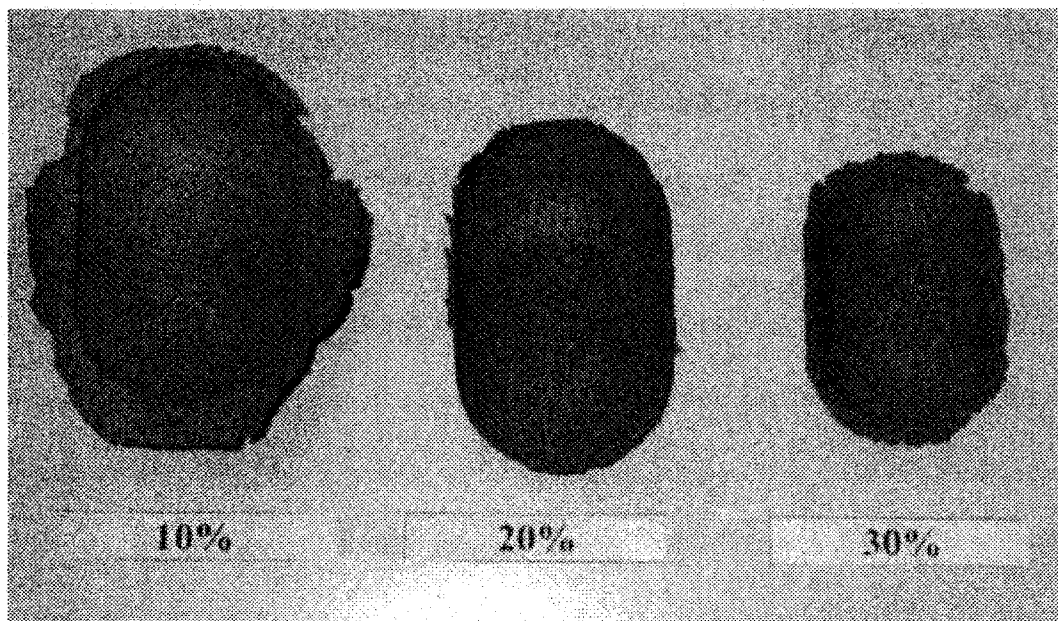
Figure 3.5. Appearance of the edible shells at different levels of PP.

potato and different levels of PP. Incorporation of PP at 20% and 30% levels gave poor baking results, whereas 10% level was acceptable.

The water content in the formulations in which mashed potato was used was likely decreased as the addition of PP was increased, resulting in the poor flowability of the mixture. Starch can be melted more completely with the addition of water and made to flow at high temperatures under pressure and shear force. In order to mold an object from starch, it must be converted into a thermoplastic matrix. The addition of water or other plasticizers enable starch to flow. Subsequently, it can be shaped into biodegradable packaging using standard thermoplastic processing techniques, such as extrusion, injection molding, or compression molding (Durfesne et al., 2000). Based on these preliminary results, the edible shells with 10% PP were chosen for further investigation.

## 3.4 Physical properties of edible shell

The thickness of the edible shells was not significantly affected by formulation (Table 3.5). This may be due to the fact that the gap between male and female molds was set at a specific distance. The weight of 2.5% PP and 5% PP edible shells were not significantly different whereas the 10% PP edible shells were significantly heavier (p<0.05) (Table 3.5). In general, the addition of fiber to baked products resulted in decreased volume (Sreenath et al., 1996; Yaseen, 2000). Toma et al. (1979) reported that loaf volume of breads containing potato peels decrease with increased addition of PP.

Muffins with 25% PP were low in height compared to muffins without PP (Arora and Camire, 1994). Abdel-Madied (1991) found that the weight of PP supplemented biscuits increased as the PP level increased. The addition of PP increases the weight of the edible shells at high level of incorporation, resulting in high density of the shells. High amount of fiber also reduced the starch content of the dough, resulting in less gel and smaller expansion on baking.

**Table 3.5. Weight and thickness of edible shells**

| Sample | Thickness (μm) | Weight (g) |
|---|---|---|
| 2.5 %PP | $99.75 \pm 0.07^a$ | $3.52 \pm 0.28^a$ |
| 5% PP | $108.50 \pm 0.05^a$ | $3.55 \pm 0.31^a$ |
| 10% PP | $101.75 \pm 0.09^a$ | $4.83 \pm 0.16^b$ |

Results are average of triplicates
a, b, c Mean scores in the same column not sharing the same superscript are significantly different ($p < 0.05$).

Results of water absorption of the edible shells are shown in Table 3.6. Water adsorption was reduced with the increase in the addition of PP. An explanation could be that the starch is more hydrophilic than cellulose. Curvelo et al., (2001) found similar results for water adsorption in thermoplastic starch-cellulosic fiber composites.

**Table 3.6. Water absorption of edible shells**

| Sample | % Water Absorption |
|---|---|
| 2.5% PP | $335.69 \pm 25.80^a$ |
| 5 % PP | $298.32 \pm 25.80^a$ |
| 10% PP | $145.83 \pm 34.13^b$ |

Means ± standard deviations ($n = 5$) followed by the same letter in a column are not significantly different ($p < 0.05$).

The lightness ($L*$) of the edible shells decreased with increased proportion of PP in the formulation because of the loss the characteristic brown color of the mashed potato when cooked (Table 3.7). This observation agreed with earlier results reported in breads formulated with PP (Toma *et al.*, 1979), muffins and oatmeal cookies made with PP ((Arora and Camire, 1994), cookies containing sugar-beet fiber (Koksel and Ozboy, 1999), and muffins made with peach fiber (Grigelmo-Miguel *et al.*, 1999). The redness (*a*) and yellowness (*b*) of three samples were not significantly different. Figure 3.6 shows the appearance of the edible shells prepared with increasing levels of PP substitution for mashed potato.

**Table 3.7.  Color of the edible shells at different level of PP**

| Sample | Color | | |
|---|---|---|---|
| | $L*$ | $a*$ | $b*$ |
| 2.5 %PP | 48.88 ± 1.38[a] | 6.29 ± 0.73[a] | 18.72 ± 1.11[a] |
| 5% PP | 47.22 ± 2.29[a] | 6.35 ± 0.68[a] | 19.17 ± 0.77[a] |
| 10% PP | 45.97 ± 1.42[b] | 5.67 ± 0.68[a] | 18.63 ± 1.46[a] |

Means ± standard deviations ($n = 4$) followed by the same letter in a column are not significantly different ($p < 0.05$).

The texture of the edible shells was affected by the incorporation of the PP (Table 3.8). The 10% PP edible shells required the greatest amount of force for puncture, resulting in hard texture. There was no statistical difference in texture observed in 2.5% and 5% PP edible shells. This change in the texture may be related to the change in volume. Adding PP to the edible shells increase their density and reduced the number of air pockets, hence increasing the force needed to puncture the shells. This result was typical for fiber-enriched products. Muffins prepared from extruded PP were harder than
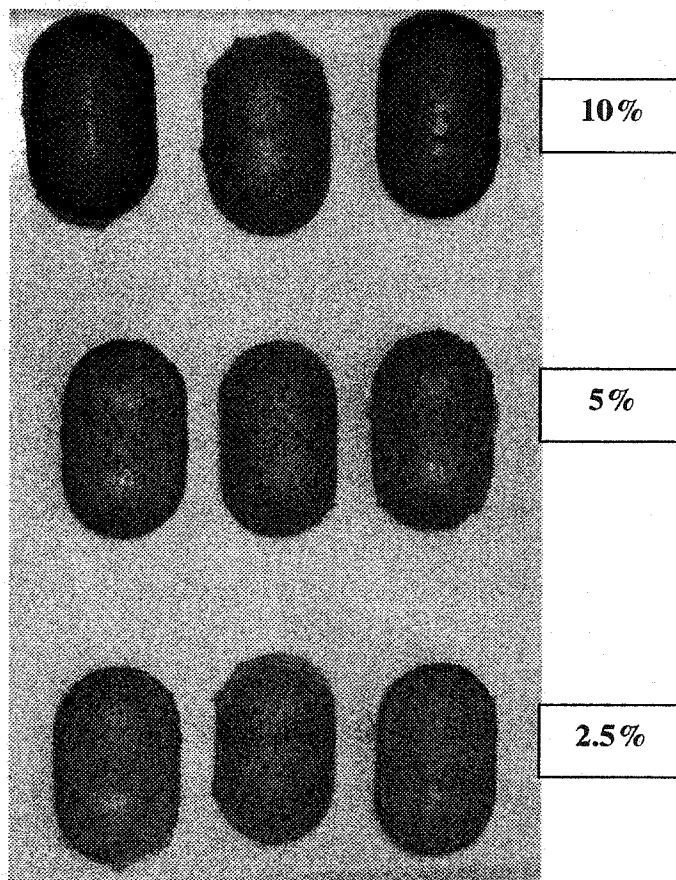
**Figure 3.6. The outer appearance of the edible shells at different levels of PP.**

controls (Arora and Camire, 1994). Instron firmness values increased significantly with increasing sugarbeet fiber additions in cookies (Koksel and Ozboy, 1999). The strength of the starch composite containing 16% fibers (by weight) increased 120% (Curvelo *et al.*, 2001).

The strength of the edible shells after absorbing water increased with the increase in the concentration of PP (Table 3.8). This may be related to the water absorption results where the edible shells with low levels of PP have higher water absorption, resulting in weak structure and low puncture resistance.

**Table 3.8. Puncture resistance (kgF) of edible shells before and after absorbing water.**

| Sample | Before absorbing water | After absorbing water |
|---|---|---|
| 2.5 %PP | $0.50 \pm 0.29^a$ | $0.006 \pm 0.007^a$ |
| 5% PP | $0.46 \pm 0.13^a$ | $0.005 \pm 0.002^a$ |
| 10% PP | $1.50 \pm 0.95^b$ | $0.188 \pm 0.046^b$ |

Means $\pm$ standard deviations ($n = 3$) followed by the same letter in a column are not significantly different ($p<0.05$).

## 3.5 Sensory evaluation

### 3.5.1 Preliminary sensory evaluation

After being stored for two weeks, the empty shells and stuffed shells were evaluated for color and texture. The color and instrumental texture of empty shells and stuffed shells are given in Table 3.9. Texture of the edible shells changed significantly after being filled with mashed potato and then frozen. The brightness, redness, and yellowness were not significantly different between the two samples.

**Table 3.9. Color and texture of the empty edible shell and stuffed edible shell.**

| Sample | Texture (KgF.) | Color | | |
|---|---|---|---|---|
| | | *L\** | *a\** | *b\** |
| **Empty** | $1.72 \pm 0.13^a$ | $50.32 \pm 1.68^a$ | $6.48 \pm 0.49^a$ | $21.29 \pm 1.34^a$ |
| **Stuffed** | $0.29 \pm 0.05^b$ | $49.35 \pm 1.47^a$ | $7.05 \pm 0.45^a$ | $22.09 \pm 1.10^a$ |

Means ± standard deviations ($n = 4$) followed by the same letter in a column are not significantly different ($p<0.05$).

In preliminary sensory evaluations, the empty edible shells containing 10% PP were evaluated and compared to the edible shells stuffed with mashed potato. The 35 untrained panelists evaluated the samples for appearance, color, texture, flavor and overall acceptability by using a 9-point hedonic scale (1, dislike extremely; 9, like extremely). A 5-point scale (5, very dark; 3, just about right; 1, very light) was used for the brightness. Results of the sensory evaluation are presented in Figure 3.7.

For the empty edible shells and stuffed shells, the mean sensory scores for appearance, color, texture, favor, and overall acceptability were higher than 6 (like slightly). The brightness of both samples was close to desired at 3 from a 5-point scale. No significant differences were found between two samples for the appearance, brightness, color, favor and overall acceptability. However, the sensory texture score for stuffed shells was significantly lower than that of empty shells. In general, the incorporation of fibers might alter the properties of food products including appearance, flavor, texture and mouthfeel (Soto-Mendivil and Vidal-Quintanar, 2001). The dietary fiber in PP is mainly insoluble fiber that might result in gritty texture and low sensory scores. Particle size may be responsible for poor texture. In this test, PP was ground and sifted through a 20 mesh screen, resulting in coarse particle size.

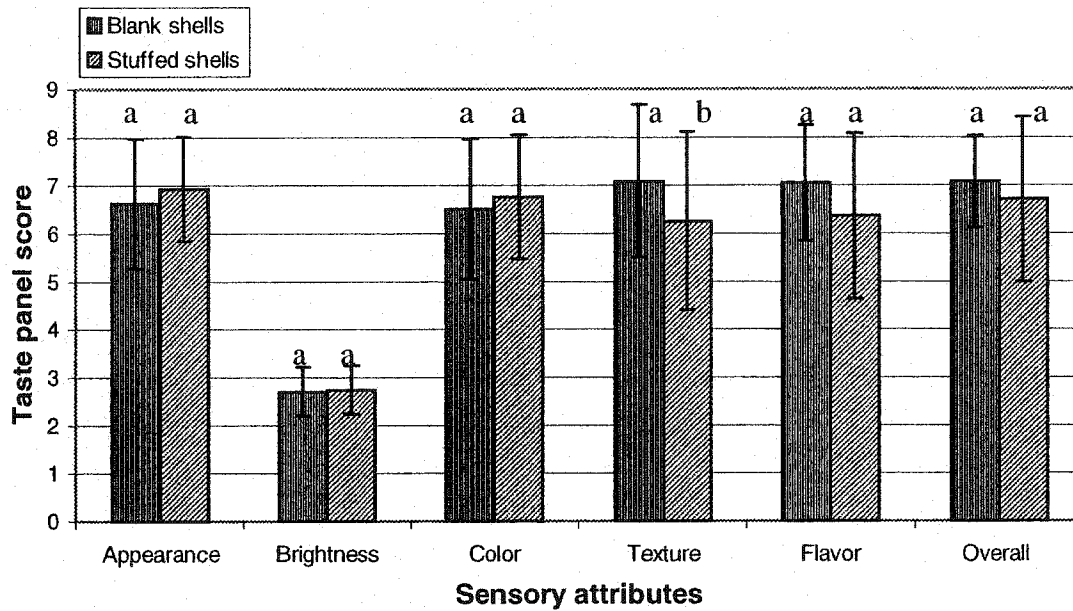**Figure 3.7.** Mean sensory score (*n* = 35) of the empty edible shells containing 10% PP and the edible shells stuffed with mashed potato. A 9-point hedonic scale (9 being like extremely and 1 being dislike extremely) was used for this organoleptic assessment. A 5-point scale was used for brightness (1= very light, 3 = just about right, 5 = very dark). Different letters above columns indicate significant differences at p < 0.05.

To see if the sensory quality of the stuffed edible shells can be further improved, pectin, carrageenan, potato starch, and monoglyceride were incorporated into the formulae which contained three different levels of PP (i.e. 2.5%, 5% and 10% PP). Potato starch, pectin, and carrageenan were added to the formulae at levels of 2.5% (w/w), and monoglyceride was incorporated at 0.01% (w/w). The particle sizes of PP were reduced to be between 420 and 200 $\mu$m, which are 40 and 80 mesh screens, respectively. Ingredients and their characteristics are described as follows:

**Mashed Potato**. Potato tubers are composed of approximately 75 to 85 % water, 20 to 23 carbohydrates, and about 2% protein. Approximately 80% by weight of potato carbohydrate is starch and is composed of amylopectin (75-79%) and amylose (21-25%) (Sieczka, 2000). Mashed potato made from fresh potatoes was used in the formulation to serve as the main continuous polymeric matrix for the edible shells due to the starch components.

**Potato starch**. Potato starch granules have several properties, namely, rapid swelling, high viscosity, good clarity, and low rate of retrogradation (Bemiller and Whistler, 1996). Like mashed potato, Potato starch was added in the formulation to serve as a continuous matrix for the edible shells, resulting in an increase of the strength of the edible shells.

**Pectin**. Pectins are major structural polysaccharides in the cell walls of plants. Commercial pectins are galacturonoglycans (poly($\alpha$-D-galactopyranosyluronic acids)) with various contents of methyl ester groups (Bemiller and Whistler, 1996). When blended with starch and plasticized with glycerol, pectin forms edible films that posses

good mechanical properties (Thakur *et al.*, 1997). Due to the fact that the edible shells will be filled with mashed potato and frozen, and the products will be reheated prior to consumption, the edible shells obtained have to be freez-thaw stable. As a result, pectin was used to enhance the mechanical properties, resulting in stability of the products after reheating.

**Carrageenan.** Carrageenan is frequently used to improve texture of food products. Their gels are freez-thaw stable. Carrageenans also maintain water content, and thus resulting in softness of meat products (Bemiller and Whistler, 1996). Carrageenans have been used to improve texture in low fat meat products (Ordonaz, *et al.*, 2001; Yang, *et al.*, 2001). The application of carrageenan to reduce oil uptake in fried snack products has been reported (Patil, *et al.*, 2001). The purpose of the addition of carrageenan was to improve the texture of the products.

**Monoglycerides.** Monoglycerides consist of a single fatty acyl chain esterified to a glycerol backbone. The free hydroxy groups of the glycerol provide hydrophilic characteristics, while the acyl chain gives lipophilic characteristics. In the food industry, monoglycerides are used as surfactants or emulsifiers; however, they also functions as conditioning agents and anti-staling agents (Boyle, 1997). The edible shells were filled with mashed potato that has high moisture content. Consequently, the integrity of edible shells after storage may be affected by the hydrophilicity of starch components. Monoglycerides are used in edible films as emulsifiers (Callegarin, *et al.*, 1997). Also, the addition of monoglyceride increased in moisture barrier in whey protein films (Bernejee and Chen, 1995) and wheat gluten films (Gontard *et al.*, 1995). The objective

of incorporation of monoglyceride to the formulation was to assist the mixing of the ingredients.

### 3.5.2 Test I

The stuffed potatoes were stored for 2 weeks before being subjected to tests I and II. The appearance of stuffed potatoes before and after microwave reheating is shown in Figure 3.8. The sensory scores of the edible shells supplemented with three different levels of PP are presented in Table 3.10. The ten-member, untrained panel did not find significant differences between three types of edible shells for color. The sample at 10% PP addition created significant difference ($p< 0.05$) in hardness, but there were no significant differences between the sample with 2.5%PP and 5%PP. This can be related to the significant differences in high puncture resistance force observed in the 10% PP edible shells. This observation agrees with previous studies on muffins made with high levels of PP (Arora and Camire, 1994). As the percentage of PP in the muffins increased, the resistance to compression increased. Oatmeal cookies prepared with 10% and 15% PP (w/w) were harder compared to control cookies (Arora and Camire, 1994). Koksel and Ozboy (1999) also reported that Instron firmness of cookies increased significantly with increasing sugarbeet fiber additions.

No significant difference was observed among the three PP levels for cohesiveness. The grittiness of the samples was affected by the amounts of PP added. The
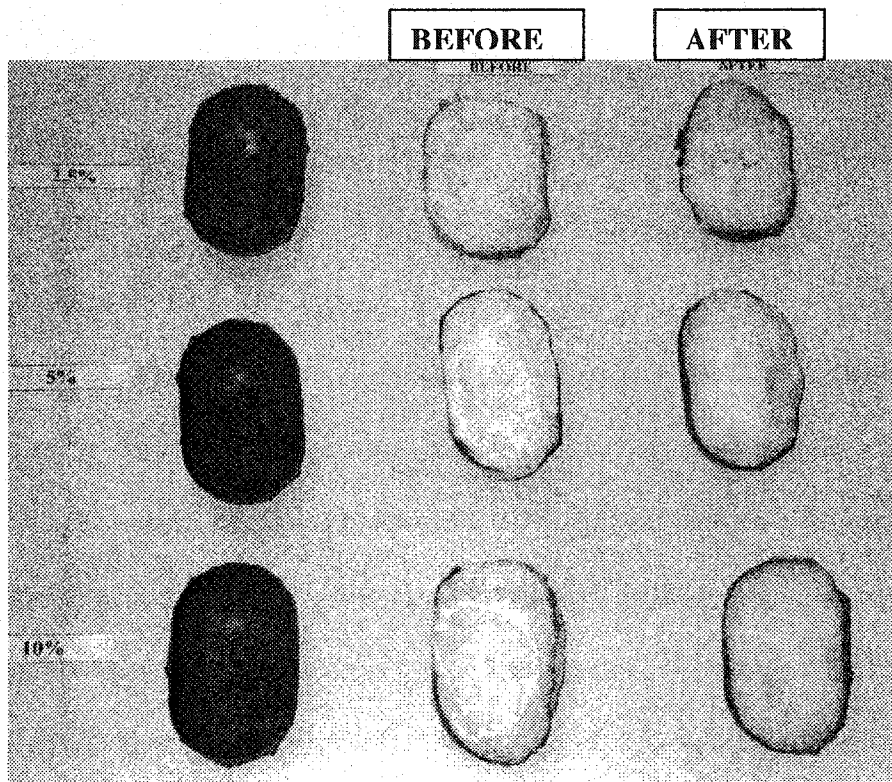
Figure 3.8. The appearance of the stuff potatoes before and after microwave reheating.

**Table 3.10. Sensory evaluation scores for edible shells supplemented with three different levels of PP.**

| Sample | Color (1 – light, 3- just about right, 5-dark) | Hardness (1 = soft, 7 = hard) | Cohesiveness (1 = loose, 7 = cohesive) | Grittiness (1 = none, 7 = much) | Texture (1, dislike extremely; 9, like extremely) | Flavor (1, dislike extremely; 9, like extremely) | Overall (1, dislike extremely; 9, like extremely) |
|---|---|---|---|---|---|---|---|
| 2.5% PP | $2.6 \pm 0.84^a$ | $3.3 \pm 0.48^a$ | $3.5 \pm 1.27^a$ | $1.4 \pm 0.70^a$ | $7.0 \pm 1.15^a$ | $6.25 \pm 1.69^a$ | $6.7 \pm 1.06^a$ |
| 5 % PP | $3.2 \pm 0.92^a$ | $3.7 \pm 1.64^a$ | $4.0 \pm 1.76^a$ | $2.5 \pm 1.08^{ab}$ | $5.9 \pm 1.59^{ab}$ | $5.4 \pm 1.34^a$ | $5.4 \pm 1.06^a$ |
| 10% PP | $3.3 \pm 0.82^a$ | $5.1 \pm 1.29^b$ | $4.9 \pm 1.73^a$ | $3.2 \pm 1.87^b$ | $5.0 \pm 2.16^b$ | $5.2 \pm 1.69^a$ | $5.2 \pm 1.99^a$ |

Means ± standard deviations ($n = 10$) followed by the same letter in a column are not significantly different ($p < 0.05$).

10% PP edible shells were found to have the most grittiness, followed by the 5% PP samples. Incorporation of increasing amount of PP into the formula led to a decrease in sensory scores for texture, favor and overall acceptability.

Samples that received lower sensory scores for texture had higher level of PP addition and had higher puncture resistance force. An explanation could be that samples with high level of PP addition were perceived by the panelists to be harder and grittier (Table 3.10). These two sensory attributes possibly influenced the texture rating scores. Similar results were observed in biscuits containing 5% and 10% PP addition (Abdel-Magied, 1991). The supplements biscuits were significantly harder to bite than control biscuits. Muffins supplemented with 25% PP were found to have an objectionable gritty mouthfeel (Arora and Camire, 1994).

### 3.5.3 Test II

Based on the results from test I, the 2.5% PP sample was chosen for further investigation. The stuffed shells reheated in a microwave oven were evaluated in comparison with reheating in a regular oven. The sensory results are shown in Table 3.11. No significant differences were observed for color, hardness, grittiness, texture and overall acceptability. However, the reheating methods used affected the crispiness of the products. The samples reheated in a regular oven were significantly higher in crispiness. This could be because water absorbed into edible shells evaporated from the shells when the high heat was used in the oven at 175°C. The samples reheated in regular oven were given higher scores in terms of flavor.

Table 3.11. Sensory evaluation scores for edible shells from two reheating methods

| Sample | Color (1 – light, 3- just about right, 5-dark) | Hardness (1 = soft, 7 = hard) | Crispness (1 = not crisp, 7 = crisp) | Cohesiveness (1 = loose, 7 = cohesive) | Texture (1, dislike extremely; 9, like extremely) | Flavor (1, dislike extremely; 9, like extremely) | Overall (1, dislike extremely; 9, like extremely) |
|---|---|---|---|---|---|---|---|
| Microwave | $2.90 \pm 0.88^a$ | $2.8 \pm 0.92^a$ | $2.8 \pm 1.40^a$ | $2.0 \pm 1.25^a$ | $6.4 \pm 1.25^a$ | $6.3 \pm 1.25^a$ | $6.3 \pm 1.49^a$ |
| Oven | $2.70 \pm 0.82^a$ | $4.2 \pm 1.40^a$ | $5.0 \pm 1.41^b$ | $2.6 \pm 1.07^a$ | $6.7 \pm 1.64^a$ | $7.5 \pm 1.18^b$ | $6.9 \pm 2.02^a$ |

Means ± standard deviations ($n = 10$) followed by the same letter in a column are not significantly different ($p < 0.05$).

When all sensory attributes were taken into account, reheating samples in regular oven was selected as the reheating method for further sensory study because the samples had higher scores for texture, flavor and overall acceptability as compared to the microwave-heated samples. Another reason is the fact that the microwave heating is not recommended for the commercial stuffed baked potatoes (President's Choice, Canada).

### 3.5.4 Consumer evaluation

After being stored for 21 days, the stuffed potato samples and control made from scooped-out baked potatoes refilled with mashed potatoes were evaluated for consumers' acceptability, texture and color. Table 3.12 illustrates the color and instrumental texture of the controls and samples. The control was darker in color. The yellowness and redness values were also higher in the control. The control was harder in texture.

**Table 3.12. Color and texture of the baked potatoes and stuffed edible shells.**

| Sample | Texture (KgF.) | Color | | |
|---|---|---|---|---|
| | | $L*$ | $a*$ | $b*$ |
| Controls | $0.3016 \pm 0.025^a$ | $41.19 \pm 2.91^a$ | $3.99 \pm 0.89^a$ | $16.79 \pm 2.69^a$ |
| Samples | $0.1355 \pm 0.0035^b$ | $48.17 \pm 2.27^b$ | $6.76 \pm 1.62^b$ | $20.76 \pm 1.66^b$ |

Means $\pm$ standard deviations ($n$ = 4) followed by the same letter in a column are not significantly different (p<0.05).

Sensory quality of appearance, brightness, color, texture, flavor and overall acceptability was judged by a panel of 56 untrained panelists. Figure 3.9 illustrates the average scores of all the sensory attributes for control compared with the 2.5% PP edible shells. No significant difference was observed between control and sample with respect

to appearance and color. The brightness of controls was rated higher than that of the samples ($p \leq 0.05$). This may be related to the lower lightness values of the samples obtained from Hunter colorimeter. Statistical evaluation of the sensory results reveals that the product made with edible shells containing 2.5% PP was preferred to the controls with respect to texture, flavor, and overall acceptability ($p < 0.05$). This may be because the control was harder in instrumental texture (Table 3.11). The harder texture may be responsible for lower texture and overall acceptability rating scores. The ingredients used may also influence the texture and flavor perceived by the panelists, resulting higher rating scores for overall acceptability.

Panelists made some comments on the samples made. For example, color of the sample was a little darker than regular baked potatoes, and some red colors may be added to make it radish brown, more like real potato. The samples were easy to chew but the shells were too crunchy and separated from the mashed potato stuffed inside. Some flavor may be added to the shells to make it more appealing. Aside from providing a whole stuffed product, the samples might be used as shells for adding mashed potato made at home.
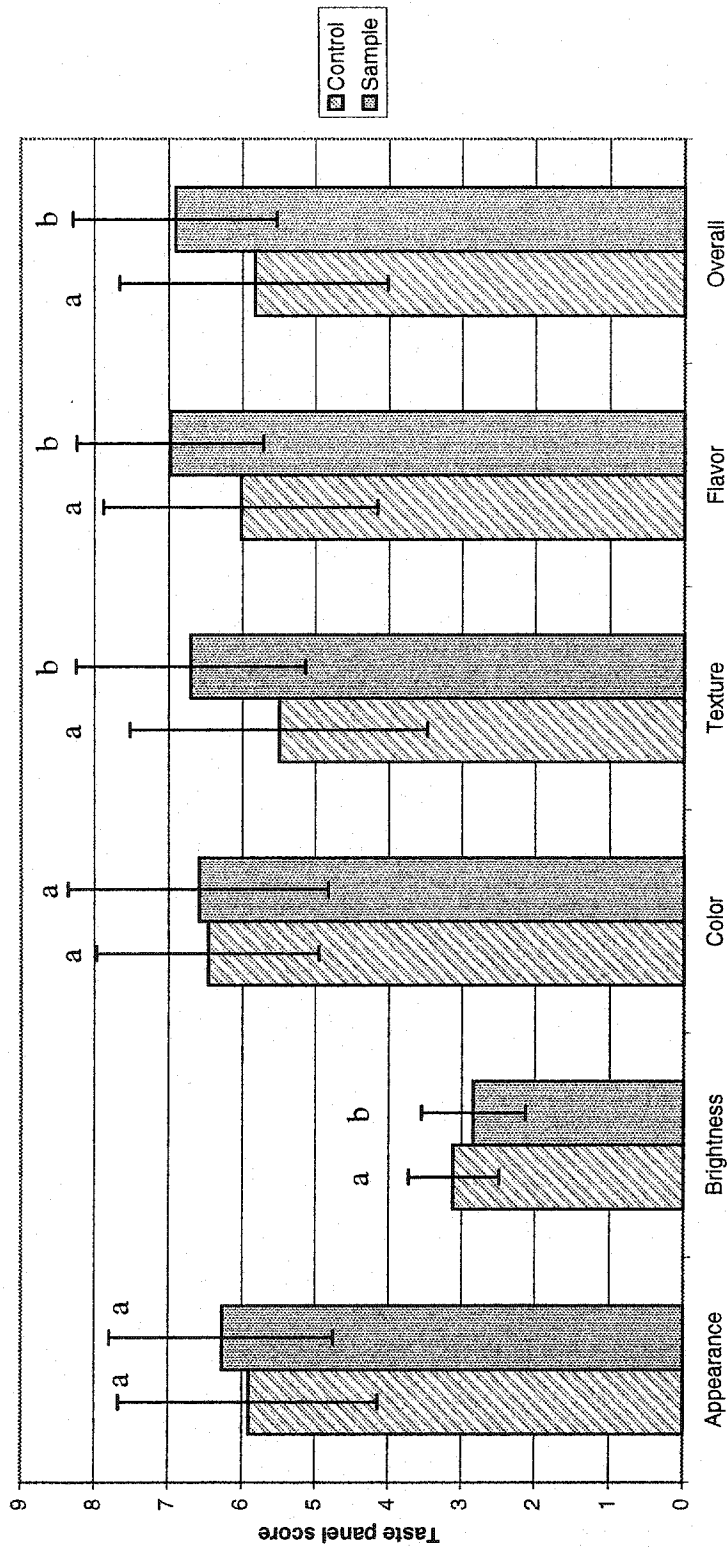
**Figure 3.9.** Mean sensory score ($n = 56$) of the 2.5% PP edible shells compared with a control made from scooped-out baked potato shells refilled with mashed potatoes. A 9-point hedonic scale (9 being like extremely and 1 being dislike extremely) was used for this organoleptic assessment. A 5-point scale was used for brightness (1 = very light, 3 = just about right, 5 = very dark). Different letters above columns indicate significant differences at p < 0.05.

# Chapter 4

## Conclusion and Recommendations

Potato peel (PP) as by-product from the steam or other peeling processes contributes to pollution and waste treatment load for the potato processing industry. In this study, a method to recover PP was developed, and chemical composition of the PP and its suitability as food ingredients were investigated. The edible shells using the potato peel as an ingredient and a product resembling a filled or baked potatoes were developed.

The results of the study revealed that PP from the steam peeling process is contaminated with dirt and sand particles, and the recovery process is required to make PP suitable for use as food ingredients. The study showed that soaking PP for 4 h followed by washing for 120 min significantly reduced dirt and sand particles.

Chemical analyses indicated that PP is a rich source of dietary fiber with high water holding capacity. The presence of glycoalkaloids in PP must be taken into consideration before utilizing it as a food ingredient. The analytical results indicated that glycoalkaloids in PP are mainly $\alpha$-chaconine and $\alpha$-solanine with concentrations of 1.18 and 0.60 $\mu g/g$, respectively. The PP may be used at a level of 11g/100g of product without exceeding the recommended limit of 20 mg glycoalkaloids /100g of product.

Edible shell as a casing for a filled potato product was developed with PP as an ingredient. The results obtained in this study suggested that addition of increasing levels of PP adversely affected physical properties and sensory characteristics of the edible shells. Increasing the concentration of PP (20% and 30%) in the formulation resulted in poor baking characteristics. Incorporation of PP increased the product weights and

produced hard texture. The strength of the edible shells before and after absorbing water was affected by the increasing addition of PP. Water absorption was reduced with increasing amounts of PP added. The supplementation of PP affected the color of the edible shells. The evidence indicated that the edible shells prepared with high percentage of PP were darker and more grayish. A stuffed potato product can be produced by filling the shell with mashed potatoes. Instrumental texture of the edible shells changed significantly after being filled with mashed potato, frozen and stored, whereas color values were not significantly different between empty and stuffed edible shells.

Sensory results for empty and stuffed shells indicated that there were no differences between the two samples for the appearance, brightness, color, flavor and overall acceptability. However, hardness of the edible shells was significantly reduced by mashed potato filling. The amounts of PP added into the formulations affected the sensory attributes. Sensory quality was poorer with higher amounts of PP added due to the grittiness and hardness of the products. The product could be reheated in either microwave or regular oven before serving with no difference in sensory characteristics. Consumer sensory evaluation results showed that the product made with edible shells containing 2.5% PP was preferred to the control which was made from scooped-out baked potato shells refilled with mashed potatoes.

## RECOMMENDATIONS

This study has indicated that PP can be recovered and used in the production of edible shells that have the shape of a half-tuber shell similar to a real baked potato shell.

However, more studies are required to provide more practical utilization of PP. The following are some suggestion for further studies:

1. An industrial scale washing should be investigated in order to recover the PP effectively and economically.

2. Even though quantitative analysis of glycoalkaloids in PP using MALDI – TOF has several advantages including ease of sample preparation, and rapid analyzing time, HPLC and immunoassays methods should also be used to confirm the results of the concentrations of α-chaconine and α-solanine in PP.

3. The concentrations of individual glycoalkaloids depend on variety of potatoes as well as harvesting and storage conditions of the potatoes. As a result, the concentrations of glycoalkaloids for each batch of PP should be determined before PP is incorporated into food products. Furthermore, the animal feeding studies as well as human sensitivity to glycoalkaloids should be conducted to guarantee the safety of this food ingredient.

4. The PP may be used in other food products at the level used in this study without exceeding safety limit. However, the maximum level used may result in poor sensory characteristics of the food products. Further research to determine optimum levels of PP in various products is recommended.

5. The formulations investigated in this study can be further developed to produce biodegradable packaging by using compression thermoforming machine. PP may be incorporated to a starch mixture to form a single-used container similar to containers made from Styrofoam. The mechanical properties of this biodegradable packaging may be improved by adding PP. Addition of PP to biodegradable packaging may also improve cost competitiveness of the product.

# Bibliography

AACC. 1983. Approved methods of the American Association of Cereal Chemists (method 56-20). American Association of Cereal Chemists, Inc., St. Paul, MN.

AACC. 1995. Approved methods of the American Association of Cereal Chemists (method 32-05). American Association of Cereal Chemists, Inc., St. Paul, MN.

AACC. 1995. Approved methods of the American Association of Cereal Chemists (method 32-21). American Association of Cereal Chemists, Inc., St. Paul, MN.

AACC. 1995. Approved methods of the American Association of Cereal Chemists (method 76.13). American Association of Cereal Chemists, Inc., St. Paul, MN.

Abell, D.C. and Sporns, P. 1996. Rapid quantitation of potato glycoalkaloids by matrix-assisted laser desorption/ionization time-of-flight mass spectrometry. J. Agric. Food Chem. 44: 2292-2296.

Abdel-Magied, M.M. 1991. Effect of dietary fiber of potato peel on the rheological and organoleptic characteristics of biscuits. Egypt. J. Food Sci. 19:293-300.

Agriculture and Agri-Food Canada. 2002. Canadian potato situation and trends. At www.agr.gc.ca

Anker, M. 1996. Edible and biodegradable films and coatings for food packaging-a literature review. SIK-Rapport No 623, 112 pp.

Anker, M., Stading, M. and Hermansson, A. 2000. Relationship between the microstructure and the mechanical and barrier properties of whey protein films. J. Agri. Food Chem. 48: 3806-3816.

Antov, M.G., Pericin, D.M., and Dimic, G.R. 2001. Cultivation of *Polyporus squamosus* for pectinase production in aqueous two-phase system containing sugar beet extraction waste. J. Biotech. 91: 83-87.

AOAC. 1995. Official Methods of Analysis (method 925.01). Association of Official Analytical Chemists, Washington, DC.

AOAC. 1995. Official Methods of Analysis (method 996.11). Association of Official Analytical Chemists, Washington, DC.

Arora, A. and Camire, M.E. 1994. Performance of potato peels in muffins and cookies. Food Res. Int. 27: 15-22.

Arvanitoyannis, I. and Biliaderis, C. 1999. Physical properties of polyol-plasticized edible blends made of methylcellulose and soluble starch. Carbohydrate Polymers. 38: 47-58.

Arvanitoyannis, I.S. and Bosnea, L.A. 2001. Recycling of polymeric materials used for food packaging: current status and perspectives. Food Rev. Int. 17: 291-346.

ASTM. 2002. Standard guide for assessing the compostability of environmentally degradable plastics (ASTM D6002-96). The American Society for Testing and Materials, West Conshohocken, PA.

ASTM. 2002. Standard test method for determining aerobic biodegradation in soil of plastic materials of residual plastic materials after composting (ASTM D5988-96). The American Society for Testing and Materials, West Conshohocken, PA.

Avena-Bustillon, R.J., Cisnenos-Zevallos, L.A., Krochta, J.M., and Salveit, M.E. 1993. Optimization of edible coatings on minimally processed carrots using response surface methodology. Trans. ASAE. 36: 801-805.

Averous, L., Fringant, C., and Moro, L. 2001. Starch-based biodegradable materials suitable for thermoforming packaging. Starch. 53: 368-371.

Balasubraminiam, V.M. , Chinnan, M.S. , Mallikarijunan, P., and Phillips, R.D. 1997. The effect of edible film on oil uptake and moisture retention of a deep-fat fried poultry product. J. Food Proc. Eng. 20: 17-29.

Baldwin, E.A. 1999. Surface treatments and edible coatings in food preservation. In, "Handbook of food preservation", Rahman, M.S. (ed). Marcel Dekker, Inc. New York, pp 577-610.

Baldwin, E.A., Nisperos, M.O., Hagenmaier, R.D., and Baker, R.A. 1997. Use of lipids in coatings for food products. Food Tech. 51: 56-62, 64.

Banerjee, R. and Chen, H. 1995. Functional properties of edible films using whey protein concentrate. J. Dairy Sci. 78: 1673-1683.

Bastioli, C. 2001. Global status of the production of biobased packaging materials. Starch. 53: 351-355.

Baysal, T. Ersus, S., and Starmans, D.A.J. 2000. Supercritical $CO_2$ extraction of beta-carotene and lycopene from tomato paste waste. J. Agri. Food Chem. 48: 5507-5511.

Bemiller, J.N. and Whistler, R.L., 1996. Carbohydrates, In "Food Chemistry", Fenema , O.R. (ed). Marcel Dekker, Inc. New York, pp 159-221.

Bomden, J.L. 1979. Waste reduction and energy use in blanching. In, " Food processing waste management", Green, J.H., and Kramer, A. (eds). AVI. Westport. CT, pp 151-174.

Boyle, E. 1997. Monoglycerides in food systems: Current and future uses. Food Tech. 51: 52-59.

Brown, D. 1993. Plastic packaging of food products: the environmental dimension. Tend Food Sci. 4: 294-300.

Budi Santosa, F.X. and Padua, G.W. 1999. Tensile properties and water absorption of zein sheets plasticized with oleic and linoleic acid. J. Agri. Food Chem. 47: 2070-2074.

Budi Santosa, F.X. and Padua, G.W. 2000. Thermal behavior of zein sheets plasticized with oleic acid. Cereal Chem. 77: 459-462.

Butler, B.L., Vergano, P.J., Testin, R.F., and Bunn, J.M. 1996. Mechanical and barrier properties of edible chitosan films as affected by composition and storage. J. Food Sci. 61: 953-955, 961.

Cage, J.K. 1991. Introduction to food packaging. In, "Food packaging technology", pp 1-13. Henyon, D.K. (ed). ASTM 04-0111130-1.

Callegarin, F., Gallo, J.Q., Debeaufort, F., and Voilley, A. 1997. Lipids and biopackaging. J. AOCS. 74: 1183-1192.

Camire, M.E. and Flint, S.I. 1991. Thermal processing effects on dietary fiber composition and hydration capacity in corn meal, oatmeal, and potato peels. Cereal Chem. 68: 645-647.

Camire, M.E., Zhao, J., and Violette, D. 1993. In vitro bile acid binding by extruded potato peels. J. Agri. Food Chem. 41: 2391-2394.

Camire, M.E., Violette, D., Dougherty, M.P., and Mclaughlin, M.A. 1997. Potato peel dietary fiber composition: effects of peeling and extrusion cooking processes. J. Agric. Food Chem. 45: 1404-1408.

Cha, J.Y., Chung, D.S., Seib, P.A., Flores, R.A., and Hanna, M.A.2001. Physical properties of starch-based foams as affected by extrusion temperature and moisture content. Indust. Crops Prod. 14: 23-30.

Chambers, J.V. 2000. Waste management: animal processing. In, " Wiley encyclopedia of food science and technology", Francis, F. J. (ed). John Wiley & Sons, Inc. New York, pp 2601-2609.

Chundakkadu, K 1999. Production of bacterial cellulases by solid state bioprocessing of banana wastes. Bioresource Tech. 69: 231-239.

Cuq, B., Gontard, N., and Guilbert, S. 1999. Effects of thermomoulding process conditions on the properties of agro-materials based on fish myofibrillar proteins. Lebensm.-Wiss.u. Technol. 31: 107-113.

Curvelo, A.A.S., de Carvalho, A.J.F., and Agnelli, J.A.M. 2001. Thermoplastic starch-cellulosic fibers composites: preliminary results. Carbohydrate Polymers. 45: 183-188.

Cybulska,G. 2000. Waste management in the food industry: an overview. Chipping Champden, Gloucestershire, UK, pp 1-135.

Debeaufort, F., Quezada-Gallo, J.A., and Voilley, A. 2000. Edible Barriers: a solution to control migration in foods. In "Food Packaging," Risch, S.J. (ed). American Chemical Society, Washington, DC., pp.9-16.

Debeaufort, F., Quezada-Gallo, J.A., and Voilley, A. 1998. Edible films and coatings: tomorrow's packaging: a review. Crit. Rev. Food Sci. 38: 299-313.

Driedger, D. R. and Sporns, P. 1999a. Glycoalkaloid concentration in Alberta potatoes determined by matrix-assisted laser desorption/ionization mass spectrometry. J. AOAC Int. 82: 908- 914.

Driedger, D. R. and Sporns, P. 1999b. Glycoalkaloid concentration in by-products of potato starch extraction as measured by matrix-assisted laser desorption/ionization mass spectrometry. J. Food Proc. Preserv. 23: 377-390.

Durfresne, A., Cavaille, J., and Vignon, M.R. 1997. Mechanical behavior of sheets prepared from sugar beet cellulose microfibrils. J. Appl. Polym. Sci. 64: 1185-1194.

Durfresne, A. and Vignon, M.R. 1998. Improvement of starch film performances using cellulose microfibrils. Macromolecules. 31: 2693-2696.

Durfresne, A., Dupeyre, D., and Vignon, M.R. 2000. Cellose microfibrils from potato tuber cells: Processing and characterization of starch –cellulose microfibril composites. J. Applied Polymer Sci. 79:2080-2092.

Environment Canada. 1989. Packaging waste management at www.ns.ec.gc.ca

Environment Protection Agency. 2000. Municipal slid waste in the United States:1999 facts and figures at http://www.epa.gov/region4/air/regulators/part70/terhune.htm .

Fadel, M. 1999. Utilization of potato chips industry by products for the production of thermostable bacterial alpha amylase using solid state fermentation system: 1. Effect of incubation period, temperature, moisture level and inoculum size. Egypt. J. Microbiol. 34: 433-445.

Fang Y., Tung, M.A., Britt, I.J., Yada, S., and Dalbleish, D.G. 2002. Tensile and barrier properties of edible films made from whey proteins. J. Food Sci. 67: 188-193.

Fang, Q., Hanna, M.A. 1999. Rheological properties of amorphous and semicrystalline polylactic acid polymers. Indust. Crops Prod. 10: 47-53.

FAO. 2002. Statistical Database at http://apps.fao.org. Agriculture data: Agricultural production- Crops Primary.

Fishman, M.L., Coffin, D.R., Konstance, R.P., and Onwulata, C.I. 2000. Extrusion of pectin/starch blends plasticized with glycerol. Carbohydrate Polymers. 41: 317-325.

Forssell, P. Lahtinen, R., Lahelin, M., and Myllarinen, P. 2002. Oxygen permeability of amylose and amylopectin films. Carbohydrate Polymers. 47: 125-129.

Foulk, J.A. and Bunn, J.M. 2001. Properties of compression-molded, acetylated soy protein films. Indust. Crops Prod. 14: 11-22.

Friedman, M. and Dao, L. 1992. Distribution of glycoalkaloids in potato plants and commercial potato products. J. Agric. Food Chem. 40: 419-423.

Friedman, M., Bautista, F.F., Stanker, L.H., and Larkin, K.A. 1998. Analysis of potato glycoalkaliods by a new ELISA kit. J. Agric. Food Chem. 46: 5097-5102.

Fu. D., Weller, C.L., and Wehling, R.L. 1999. Zein: properties, preparations, and applications. Food Sci. Biotehnol. 8: 1-10.

Garcia, M.A., Martino, M.N., and Zaritzky, N.E. 2000. Lipid addition to improve barrier properties of edible starch-based films and coatings. J. Food Sci. 65: 941-947.

Garrote, R.L., Bertone, R.A., Silva, E.R., Coutaz, V.R. and Avalle, A. 1998. Heat and NaOH penetration during chemical peeling of potatoes. Food Sci. Tech. Int. 4: 23-32.

Garrote, R.L., Silva, E.R., and Bertone, R.A. 2000. Effect of thermal treatment on steam peeled potatoes. J. Food Eng. 45: 67-76.

Gennadios, A. and Weller, C.L. 1990. Edible films and coating from wheat and corn protein. Food Technol. 44: 63-69.

Gennadios, A., Hanna, M.A., and Kurth, L.B.1997. Application of edible coatings on meats, poultry and seafoods: a review. Lebensm-Wiss.u. Technol. 30: 337-350.

Gennadios, A., Weller, C.L., and Hanna, M.A. 2000. Edible films and coatings. In "Wiley encyclopedia of food science and technology", Francis, F. J. (ed). John Wiley & Sons, Inc. New York, pp 579-584.

Glenn, G.M, Orts, W.J., Nobes, G.A.R., and Gray, G.M. 2001. In situ laminating process for baked starch-based foams. Indust. Crops Prod. 14: 125-134.

Gontard, N., Guilbert, S., and Cuq, J.L. 1993. Water and glycerol as plasticizer affect mechanical and water vapor barrier properties of and edible wheat gluten film. J. Food Sci. 58: 206-211.

Gontard, N., and Guilbert, S. 1994. Bio-packaging: technology and properties of edible and/or biodegradable packaging materials from agricultural origins. In "Food Packaging and Preservation", Matholuthi, M. (ed). Blackie Academic& Professional, UK, pp. 159-182.

Gontard, N., Marchesseau, S., Cuq, J.L., and Guilbert, S. 1995. Water vapour permeability of edible films of wheat gluten and lipids. Int. J. Food Sci. Tech. 30: 49-56.

Griffin, G.J.L. 1994. Gelatinized starch product. In, "Chemistry and technology of biodegradable polymers", Griffin, G.J.L (ed). Blackie Academic & Professional. UK, pp 159-182.

Griegelmo-Miguel, N., Carreras-Boladeras, E., and Martin-Belloso, O. 1999. Development of high-fruit-dietary-fiber muffins. Eur. Food Res. Technol. 210: 123-128.

Guilbert, S., Cuq, B., and Gontard, N. 1997. Recent innovations in edible and/or biodegradable packaging materials. Food Add. Contam.14: 741-751.

Hagenmaier, R.D. and Baker, R.A.1995.Layered coatings to control weight loss and preserve gloss of citrus fruit. HortScience. 30: 296-298.

Hang, Y.D. 2000. Waste management: fruits and vegetables. In, " Wiley encyclopedia of food science and technology", Francis, F. J. (ed). John Wiley & Sons, Inc. New York, pp 2610-2614.

Hang, Y.D. and Woodams, E.E. 2000. Corn husks: a potential substrate for production of citric acid by *Aspergillus niger*. Lebensmittel-Wissenschaft-und-Technologie. 33: 520-521.

Hanlon, J.F., Kelsey, R.J., and Forcinio, H. 1998. Packaging and the environment. In, " Handbook of packaging engineering", Kelsey, R.J. (ed). Technomic Publishing Co., Inc. Lancaster, USA, pp 655-676.

Heerden, I-van, Cronje, C., Swart, S.H., and Kotze, J.M. 2002. Microbial, chemical and physical aspects of citrus waste composting. Bioresource Tech. 81: 71-76.

Hoffman, K.L., Han, I.V. and Dawson. D.L. 2001. Antimicrobial effects of corn zein films impregnated with nisin, lauric acid, and EDTA. J. Food Prot. 64: 885-889.

Hornstein, R.R. and Landrum, G.F. 1997. Molded biodegradable packaging. United States Patent. US 5623815.

Jangchud, A. and Chinnan, M.S. 1999. Peanut protein film as affected by drying temperature and pH of film froming solution. J. Food Sci. 64: 153-157.

Jelen, P. 1983. Reprocessing of whey and other dairy waste for use as food ingredients. Food Technol. 37: 81-84.

Joshi, V.K. and Sandhu, D.K. 1996. Preparation and evaluation of an animal feed byproduct produced by sold-state fermentation of apple pomace. Bioresource Tech. 56: 251-255.

Jurjanz, S., Collin-Schoellen, O., Gardeur, J.N., and Laurent, F. 1998. Alteration of milk fat by variation in the source and amount of starch in a total mixed diet fed to dairy cows. J. Dairy Sci. 81: 2924-2933.

Kampf, F.N. and Nussinovitch, A. 2000. Hydrocolloid coating of cheese. Food Hydrocolloids. 14: 531-537.

Katz, F. 1998. Packaging source reduction. Food Technol. 52:82.

Kennedy, M.J. 1994. Apple pomace and kiwifruit: processing options. Australasian Biotechonol. 491: 43-49.

Kittur, F.S., Kumar, K.R., and Tharanathan, R.N. 1998. Functional packaging properties of chitosan films. Z. Lebensm. Unters. Forsch. A. 209: 44-47.

Koksel, H. and Ozboy, O. 1999. Effects of sugarbeet fiber on cookie quality. Zuckerindustrie. 124: 542-544.

Krochta, J. M. and De Mulder-Johnston, C. 1997. Edible and biodegradable films. Food Tech. 51: 61-74.

Kroyer, G.Th. 1995. Impact of food processing on the environment – an overview. Lebensm. Wiss.u. Technol. 28: 547-552.

Lai, H. and Padua, G.W. 1997. Properties and microstructure of plasticized zein films. Cereal Chem. 74: 771-775.

Lai, H. and Padua, G.W. 1998. Water vapor barrier properties of zein films plasitcized with oleic acid. Cereal Chem. 75: 194-199.

Laughlin, R.G.W., Forrestall, B., and McKim, M. 1984. Food processing industry technical manual: waste abatement, reuse, recycle and reduction opportunities in industry. Environment Canada, section 1.11-10.5.

Larmond, E. 1977. Laboratory methods for sensory evaluation of food. Canada Department of Agriculture, Ottawa, pp 5-72.

Lawton, J.W. and Fanta, G.F. 1994. Glycerol-plasticized films prepared from starch-poly (vinyl alcohol) mixtures: effect of poly (ethylene-co-acrylic acid). Carbohydrate Polymers. 23: 275-280.

Lazarov, K. and Werman, M.J. 1996. Hypocholesterolaemic effect of potato peels as a dietary fiber source. Med. Sci. Res. 24: 581-582.

Malmberg, A.G. and Theander, O. 1984. Free and conjugated phenolic acids and aldehydes in potato tubers. Swed. J. Agric. Res. 14: 119-125.

Managhi, R. 1993. Energy from waste. In, " Plastic waste management" Mustafa, N. (ed). Marcel Dekker , Inc., New York, pp369-405.

Mate, J.L. and Krochta, J.M. 1998. Oxygen uptake model for uncoated and coated peanuts. J. Food Eng. 35: 299-312.

Matti, H. 2001. Milk sugars and minerals as ingredient. Int. J. Dairy Technol. 51: 61-63.

Mauer, L.J., Smith, D.E., and Labuza, T.P. 2000. Water vapor permeability, mechanical, and structural properties of edible β-casein films. Int. Dairy J. 10: 353-358.

McHugh, T.H. and Krochta, J.M. 1995. Milk protein-based edible films made of milk proteins. J. Dairy Sci. 78: 2563-2583.

McHugh, T.M. 2000. Protein-lipid interactions in edible films and coatings. Nahrung. 44: 148-151.

McKee, L.H. and Latner, T.A. 2000. Underutilized sources of dietary fiber: a review. Plant Foods for Human Nutrition. 55: 285-304.

Menzies, D. 1998. Industry masters the 3-R mantra. Food in Canada. 58: 14.

Mingxia, L. and Damodaran, S. 1999. Effect of transglutaminase-catalyzed polymerization of beta-casein on its emulsifying properties. J. Agri. Food Chem. 47: 1514-1519.

Murray, W. 1995. The garbage crisis: traditional solutions. Government of Canada at http://dsp-psd.pwgsc.gc.ca//Collection-R/LoPBdP/BP/bp407-e.htm

Natu, R.B., Mazza, G., and Jadhav, S.J. 1991. Waste utilization. In "Potato: production, processing, and products", Salunkhe, D.K., Kadam, S.S., and Jadhave, S.J. (eds). CRC Press, Florida, pp 175-199.

Nigam, P., Singh, D., and Pandey, A. 2001. Utilization of agricultural and food waste and by-products by biotechnology. Agric. Food Ind. Hitech. 12: 26-29.

Nini, D. and Gimenez-Mitsotakis, P. 1994. Creative solutions for bakery waste effluent. In, "Environmentally responsible food processing", Niranjan, K., Okos, M.R., and Rankowitz, M. (eds). American Institute of Chemical Engineers, New York, pp 63-65.

Niranjan, K. and Shilton, N.C. 1994. Food processing wastes: their characteristics and an assessment of processing options. In, "Environmentally responsible food processing", Niranjan, K., Okos, M.R., and Rankowitz, M. (eds). American Institute of Chemical Engineers, New York, pp 1-7.

Oauhara, B., Simard, R.E., Piette, G., and Begin, A. 2000. Inhibition of surface spoilage bacteria in processed meats by application of antimicrobial films prepared with chitosan. Int. J. Food Micro. 62: 139-148.

Ockerman, H.W. and Hansen, C.L. 2000. Animal-processing waste disposal, reduction, and utilization. In, "Animal by-product processing and utilization", Ockerman, H.W., and Hansen, C.L (eds). Technomic Publishing Co.Inc., Pennsylvania, pp 457-509.

Okamoto, M. and Ushikubo, A. 2001. Recycling by food processing industries. Biocycle. 42: 63-64.

Ooraikul, B. and Aboagye, N. 1986. Synthetic Food Product. US Patent No 4582710.

Orr, P.H., Toma, R.B., Munson, S.T., and D' Appolonia, B. 1982. Sensory evaluation of breads containing various levels of potato peels. Am. Potato J. 59: 605-611.

Ouattra, B., Simard, R.E., Piette, G., Begin, A., and Holley, R.A. 2000. Inhibition of surface spoilage bacteria in processed meats by application of antimicrobial films prepared with chitosan. Int. J. Food Microb. 62: 139-148.

Ordonez, M., Rovira, J., and Jaime, I. 2001. The relationship between the composition and texture of conventional and low-fat frankfurters. Int. J. Food Sci. Tech. 36: 749-758.

Ozdemir, M and Floros, J.D. 2001. Analysis and modeling of potassium sorbate diffusion through edible whey protein films. J. Food Eng. 47: 149-155.

Padgett, T., Han, I.Y., and Dawson, P.L. 1998. Incorporation of food grade antimicrobial components into biodegradable packaging films. J. Food Prot. 61: 1330-1335.

Paramawati, R., Yoshino, I., and Isobe, S. 2001. Properties of plasticized-zein film as affected by plasticizer treatments. Food Sci. Tech. Res. 7: 191-194.

Park, H.J., Kim, S.H., Lim, S.T. Shin, D.H., Choi, S.V., and Hwang, K.T. 2000. Grease resistance and mechanical properties of isolated soy protein-coated paper. J. AOAC. 77: 269-273.

Patil, S.J., Singhal, R.S., and Kulkarni, P.R. 2001. Screening of different hydrocolloids for improving the quality of fried papad. Eur. J. Lipid. Sci. Technol. 103: 722-728.

Pearson, D. 2002. Alberta-a respected potato power house. Alberta Food for Thought. Winter: 22-23.

Petersen, K, Nielsen, P V., Bertelsen, G., Lawther, M., Olsen,M.B., Nilsson, N.H., and Moretensen, G. 1999. Potential of biobased materials for food packaging. Trends Food Sci. Tech. 10: 52-68.

Petersen, K., Nielsen, P.V., and Olsen, M.B. 2001. Physical and mechanical properties of biobased materials - starch, polylactate and polyhydroxybutyrate. Starch. 53: 356-361.

Raiz, M.N. 1999. Processing biodegradable packaging material from starches using extrusion technology. J. AOAC. 82: 908-914.

Rakotoninainy, A.M., Wong, Q., and Padua, G.W. 2001. Evaluation of zein film as modified atmosphere packaging for fresh broccoli. J. Food Sci. 66: 1108-1111.

Rakatoniraniny, A.M., and Padua, W.G. 2001. Effects of lamination and coating with drying oils on tensile and barrier properties of zein films. J. Agri. Food Chem. 49: 2860-2863.

Rampon, V., Robert, P., Nicolas, N., and Dufour, E. 1999. Protein structure and network orientation in edible films prepared by spinning process. J. Food Sci. 64: 313-316.

Rayner, M., Cioilfi, V., Maves, B., Stedman, P., and Mittal, G.S. 2000. Development and application of soy-protein films to reduce fat intake in deep-fried foods. J. Sci. Food Agri. 80: 777-782.

Rindlav-Westling, A., Stading, M., Hermansson, A.M., and Gatenholm, P. 1998. Structure, mechanical and barrier properties of amylose and amylopectin films. Carbohydrate Polymers. 36: 217-224.

Robe, K. 1973. Hot gas blanching reduces waste water 99%, reduces BOD 96%. Food Proc. 34: 12-13.

Rodriguez de Sotillo, D., Hadley, M., and Wolf-Hall, C. 1998. Potato peel extract: a nonmutagenic antioxidant with potential antimicrobial activity. J. Food Sci. 63: 907-910.

Roper, H. and Koch, H. 1990. The role of starch in biodegradable thermoplastic materials. Starch. 42: 123-130.

Rothfuss, R.K. 1997. The case for reusable packaging. Food Proc. 58: 86-87.

Roy, S., Gennodois, A., Weller, C.L., and Testin, R.F. 2000. Water vapor transport of a cast wheat gluten films. Indust. Crops Prod. 11: 43-50.

Selvakumar, P., Ashakumury, L., and Pandey, A. Biosynthesis of glucoamylase from Aspergillus niger by solid-state fermentation using tea waste as the basis of a solid substrate. Bioresource Tech. 65: 83-85.

Shafiq-Alam, M.P. and Shashi, P. 2001. Efficacy of casein coating on storage behavior of kinnow. J. Food Sci. Tech. India. 38: 235-238.

Shaw, N.B., Monahan, F.J., O'Riordan, E.D., and O' Sullivan, M. 2002. Physical properties of WPI films plasticized with glycerol, xylitol, or sorbitol. J. Food Sci. 67: 164-167.

Shih, F.F. 1998. Non-food use of proteins; film-forming properties and edible films of plant proteins. Nahrung. 42: 254-256.

Shogren, R.L. 1996. Preparation, thermal properties, and extrusion of high-amylose starch acetates. Carbohydrate Polymers. 29: 57-62.

Sieczka, J.B. 2000. Potatoes and potato processing. In "Wiley encyclopedia of food science and technology", Francis, F.J. (ed). John Wiley & Sons, Inc. New York, pp 1933-1937.

Smith, D.B., Roddick, J.G., and Jones, J.L. 1996. Potato glycoalkaloids: some unanswered questions. Trends Food Sci. Tech. 7: 126-131.

Smith, T.J. and Huxsol, C.C. 1987. Peeling potatoes for processing. In, "Potato processing," 4th ed,. Talburt, W.F., and Smith, O. (eds). AVI Pub. Co., Inc., Westport, CT, pp 333-369.

Soares, N.F.F. and Hotchkiss, J.H. 1998. Bitterness reduction in grapefruit juice through active packaging. Packaging Tech. Sci. 11: 9-18.

Sotelo, A. and Serrano, B. 2000. High-performance liquid chromatographic determination of the glycoalkaloids α-solanine and α-chaconine in 12 commercial varieties of Mexican potatotoes. J. Agric. Food Chem. 48: 2472-2475.

Sothornvit, R. and Krochta, J.M. 2001. Plasticizer effect on mechanical properties of β-lactoglobulin films. J. Food Eng. 50: 149-155.

Soto-Mendivil, E.A., and Vidal-Quintanar, R.L. 2001. Evaluation of nixtamalized corn hulls as fiber source in baking products. Food Sci. Tech. Int. 7: 355-361.

Sporns, P. and Wang, J. 1998. Exploring new frontiers in food analysis using MALDI-MS. Food Res. Int. 31: 181-189.

Sreenath, H.K., Sudarshanakrishna, K.R., Prasad, N.N., and Santhanam, K. 1996. Characteristics of some fiber incorporated cake preparations and their dietary fiber content. Starch. 48: 72-76.

Stuchell, Y.M. and Krochta, J.M. 1995. Edible coatings on frozen King salmon: effect of whey protein isolate and acetylated monoglycerides on moisture loss and lipid oxidation. J. Food Sci. 60: 28-31.

Thakur, B.R., Singh, R.K., and Handa, A.K.1997. Chemistry and uses of pectin. Crit. Rev. Food Sci. Nutrit. 37: 47-73.

Toma, R.B., Orr, P.H., D Appolonia, B., Dintzis, F.R., and Tabekhia, M.M. 1979. Physical and chemical properties of potato peel as a source of dietary fiber in bread. J. Food Sci. 44: 1403-1407.

Tudorica, C.M., Kuri, V., and Brennan, C.S. 2002. Nutritional and physicochemical characteristics of dietary fiber enriched pasta. J. Agric. Food Chem. 50: 347-356.

Vrataninia, D.L. and Zabik, M.E. 1979. Dietary fiber sources for baked products bran in sugar-snap cookies. J. Food Sci. 43: 1590-1594.

Villegas, R., O'Corner, T.P., Kerry, J.P., and Buckley, D.J. 1999. Effect of gelatin dip on the oxidation and color stability of cooked ham and bacon pieces during frozen storage. Int. J. Food Sci. Tech. 34: 385-389.

Watts, B.M., Ylimaki, G.L., Jeffery, L.E., Elias, L.G. 1989. Basic sensory method for food evaluation. The International Development Research Centre, Ottawa, Canada, pp 1-136.

Williams, R. and Mittal, G.S. 1999. Water and fat transfer properties of polysaccharide films on fried pastry mix. Lebensm.-Wiss.u. Tchnol. 32: 440-445.

Won-Seok, C. and Han, J.H. 2001. Physical and mechanical properties of pea-protein-based edible films. J. Food Sci. 66: 319-322.

Wong, A.L., Chua, H., Lo, W.H., and Yu, P.H.F. 2000. Synthesis of bioplastics from food industry wastes with activated sludge biomass. Water Sci. Tech. 41: 55-59.

Wong, D.W.S., Gregorski, K.S., Hudson, J.S., and Paulath, A.E. 1996. Calcium alginate films: thermal properties and permeability to sorbate and ascorbate. J. Food Sci. 61: 337-341.

Wu, Y., Weller, C.L., Hamonz, F., Cuppett, S., and Schucpf, M. 2001. Moisture loss and lipid oxidation for precooked ground-beef patties packed in edible starch-aginate-based composite films. J. Food Sci. 66: 481-493.

Xie, L., Hettiarachchy, N.S., Ju, Z.Y., Meullenet, J., Wang, H., Slavic, M.F., and Janes, M.E. 2002. Edible film coating to minimize eggshell breakage and reduce post-wash bacterial contamination measured by dye penetration in eggs. J. Food Sci. 67: 280-284.

Xu, S., Chen, X., and Sun, D.W. 2001. Preservation of kiwifruit coated with an edible film at ambient temperature. J. Food Eng. 50: 211-216.

Yang, A, Keeton, J.T., Beilken, S.L., and Chen, G.Q. 2001. Evaluation of some binders and fat substitutes in low-fat frankfurters. J. Food Sci. 66: 1039-1046.

Yaseen, A.A.E. 2000. Formulating a new high fiber rusk for production on commercial scale. Nahrung. 44:110-113.

Yu, P.H., Chua, H., Huang, A.L., Lo, W., and Chen, G.Q. 1998. Conversion of food industry wastes into bioplastics. App. Biochem. Biotech. 70-72: 603-614.

Zhao, J., Camire, M.E., Bushway, R.J., and Bushway, A.A. 1994. Glycoalkaloid content and in vitro glycoalkaloid solubility of extruded potato peels. J. Agric. Food. Chem. 42: 2570-2573.