University of Alberta

Development of Vegetarian Products with Added Rhubarb Fiber

by

Stephanie Man Sai Shum ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of **Master of Science**

in

Food Science and Technology

Department of Agricultural, Food and Nutritional Science

Edmonton, Alberta

Fall 1998

0-612-34417-7

University of Alberta

Library Release Form

Name of Author: Stephanie Man Sai Shum

Title of Thesis: Development of Vegetarian Products with Added Rhubarb Fiber

Degree: Master of Science

Year this Degree Granted: 1998

Block C, 18/F

130 Market Street

Tsuen Wan, Hong Kong.

Date: May 15, 1998

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **Development of Vegetarian Products with Added Rhubarb Fiber** by **Stephanie Man Sai Shum** in partial fulfillment of the requirements for the degree of **Master of Science** in **Food Science and Technology**.

Dr. B. Ooraikul, Supervisor

Dr. L. Ozimek

Dr. M. Palcic

Dr. P. Sporns

Date: May 15, 1998.

ABSTRACT

Absence of fibrous structure results in lack of chewiness in many vegetarian products. The objective of this research was to address this deficiency by incorporate rhubarb fiber into the products. Vegetarian jerky and patty were made using tofu, rhubarb fiber, wheat gluten, flavor and color. The prototypes were rated superior to commercial vegetarian products, but inferior to meat products. Texture measurements revealed that firmness and chewiness of the prototypes were similar to those for meat products, and were much higher than those of commercial vegetarian products. SEM micrographs show that the mixture of tofu and gluten bonded with rhubarb fiber both inside and outside the fiber coils, which contributed to firmness and chewiness of the products. The prototypes were high in protein, calcium and dietary fiber, but low in fat as compared to most of the commercial products. Oxalate content of rhubarb fiber was significantly reduced during processing. Microbial analyses indicated that the jerky has to be drier to reduce microbial growth. The patty may be frozen to minimize growth of microorganisms. The prototype jerky was cheaper than meat jerky. Price of prototype patty was higher than meat patty but can be reduced by partial substitution of gluten with starch.

ACKNOWLEDGEMENT

I would like to thank my supervisor, Dr. B. Ooraikul, for his advice, his encouragement and his patience. From him, I learned how to be a skillful researcher and writer. He is creative, full of knowledge but is humble and keep learning. He always encourages me that if I can imagine of a product, I should never give up and work as hard as I can, and I will get it at the end. I will always keep this in mind.

I would like to thank Dr. P. Sporns and Dr. L. Ozimek for their participation as committee members for the past two years and for their guidance. I would like to thank Dr. M. Palcic for her active participation as an examining committee member.

I would like to thank George Braybrook, Len Steele, and Dr. Goh, for their technical support. I would also like that thank the Alberta Agricultural Research Institute for the advice on choosing an antifoaming agent.

Finally, I would like to thank God for giving me a warm family, especially my brother who helps me all the time, and my friends who encourage me during the study. I would like to express my deepest thanks to my father for his moral support and encouragement. Once again, I would like to express my deepest appreciation to my friend and my supervisor, Aj. Buncha.

Table of Contents

List of Figures

List of Plates

CHAPTER 1
INTRODUCTION AND LITERATURE REVIEW

1.1. General Introduction

In recent years, the market for vegetarian food has been expanding due to the increasing number of vegetarians (Realeat Survey, 1984-1993) and health-concerned individuals. The number as well as the varieties of vegetarian products have increased. A number of reasons give rise to the increasing number of consumers of vegetarian products. Many of them consume these products not only to fulfill their dietary requirements, but also to accommodate changes in their concepts on meat consumption. Consumer's perception of meat has changed dramatically over the past 50 years. Many consumers became more concerned about their weight and health and thus, reduced their meat consumption (Breidenstein, 1988). Some consumers believe meat consumption has adverse effects on their health; some believe in animal rights movement; and some belong to religions that promote meatless diets.

Many of the commercial vegetarian products currently available are made with soybean curd (tofu) as the main ingredient. However, because of the soft and crumbly texture of tofu, these products, in turn, are usually soft and lack chewability. The purpose of the current research was to develop formulations and processing techniques for vegetarian products with an attempt to improve their texture. The technology developed may also be used to produce other products which would have improved texture.

1.1.1. Vegetarian Market

Due to the growth of vegetarianism, the increased number of health-concerned individuals, different personal beliefs, and food safety concern of some consumers, the market potential for vegetarian products has greatly expanded. As a result, the demand for vegetarian products is increasing in parallel with the rapid increase in the number of vegetarian food manufacturers in recent years. Some of the vegetarian products available in Edmonton are listed in Table 1.1. They include vegetarian burger patties, vegetarian seafood, and vegetarian sausages, etc.

Table 1.1 - Commercial vegetarian products available in Edmonton

Company Name	Products Produced	Price in 1998, CAN $	Remarks
Yves Veggie Cuisine Vancouver, B.C.	Vegetarian weiners, burger patty, ham, sausages and ground "meat"	$ 2.27 for 2 Burger Patties	• The company was established in 1985. The company's annual sale was $ 17 million in 1996 (Lamey, 1996). • Carrageenan, soy and wheat products are used in all the products.
Sunrise Soya Foods Vancouver, B.C.	Variety of tofu products as well as the new vegetarian burger patties	$ 2.00 for 2 Burger Patties	All the products are tofu based.
Big Mountain Foods Vancouver, B.C.	Burger patties	$ 5.00 for 4 Burger Patties	The burger patties are lentil based.
Wholesome and Hearty Foods Inc. USA	Burger patties	$ 4.59 for 4 Burger Patties	The burger patty contains no soy or wheat products and is made of brown rice, cheese, egg whites, bulgur wheat, tapioca starch and vegetable gum.
Whole Perfect Food Co. Ltd. Hong Kong	Vegetarian gluten patty and vegetarian squid, abalone, prawns, fish balls, etc.	$ 2.99/ 200 g	The vegetarian squid, abalone, and prawns are made of taro powder.
Shin-der Enterprise Co. Ltd. Taiwan	Vegetarian tuna and chicken	Over $ 4.19/ 200 g	• The products are made of spun soy protein fiber and are very salty. • The vegetarian chicken product has a piece of soy film which simulates chicken skin.

At present, there is no Canadian jerky designed specifically for vegetarians. However, a similar form of product, i.e. fruit leather, is available, e.g. those from Kettle Valley Dried Fruits Ltd. (Summerland, B.C.) and Sun-rype Products Ltd. (Kelowna, B.C.). Fruit leather is made of fruit puree with or without guar gum. In Asia, there are some partially dried tofu products which are flavored (with or without frying) and are consumed as jerky. Some of these products do not contain meat flavors and are thus suitable for vegetarians. The texture of the fried tofu product is chewy, but it contains high amount of fat; whereas, the non-fried products are very dry and crumbly. The price and characteristics of fruit leather products and partially dried tofu products are listed in Table 1.2. There are at least 5 brands of real meat jerky available on the market in Edmonton. Their manufacturers, prices and characteristics are listed in Table 1.3.

In 1997, the sales of salty snacks (3.8% of total convenience store sale) in the United States was slightly lower than candy and chewing gum (4.1%) but was higher than bread and cakes (3%) and groceries (3%). The total value of snack sale was US$ 151.9 billion (Sloan, 1997b). The market for salty snack food appears promising. Considering the popularity of high protein meat jerky, which is also high in price, it is conceivable that vegetarian jerky can become a popular item if its sensory quality can be made comparable to meat jerky, with good nutritional value, and with prices lower than meat jerky.

1.1.2. Common Problems in Food Analogues

Vegetarian "meat-like" products lack the natural chewability or mouthfeel of natural meat products because they are made with textureless plant protein as a basic ingredient. The protein matrix, which serves as the basic structure of these products, is formed by chemical coagulation (e.g. soybean protein), or by mixing with water to form a dough (e.g. wheat gluten). Lack of fiber strands in the structure of both soybean curd and gluten dough makes the chewing of these products less satisfactory as compared to natural meat products.

In the case of fruit leather, the fruit fiber is finely pureed before drying. Without the use of a strong binding agent, the leather lacks chewability. On the other hand, the

Table 1.2 – Fruit leather and partially dried tofu products available in Edmonton

Company Name	Products Produced	Price in 1998, CAN $	Remarks
Kettle Valley Dried Fruits Ltd. Summerland, B.C.	Fruit leather	$ 0.33/15 g	The products provide 0.2 g of protein.
Sun-rype Products Ltd. Kelowna, B.C.	Fruit leather	$ 0.33/15 g	• Guar gum is used in the products. • The products provide 0.2 g of protein
Hsin Tung Yang Co. Ltd. Taiwan	Partially dried tofu	$ 1.39/100 g	The product is chewy but contains 13 g of fat in 42 g of product.
Jin Mei Shian Co. Ltd. Taiwan	Partially dried tofu	$ 1.39/100 g	The product is dry and crumbly.

Table 1.3 – Commercial meat jerky available in Edmonton

Company Name	Price in 1998, CAN $	Remarks
Bridgford Foods Corp. Chicago, IL.	$4.00/ 35 g	This jerky is very dry, very hard, and very chewy Bridgford also produces a kippered beef which has little moisture or oil, very salty and tastes similar to ham. The price for 57 g of kippered beef is $ 4.00.
McSweeney (Canada) Ltd. Calgary, AB.	$ 4.99/ 100 g	• The jerky has very little moisture or oil, very salty and very hard and chewy. • McSweeney also produce a Teriyaki beef jerky which is easier to chew and is similar to other oriental beef jerky in taste.
Van's Quality Foods Edmonton, AB.	$ 4.30/ 100 g	This brand of jerky is relatively cheap but is also very hard, chewy, salty and smoky.
Jimmy's Fine Food Ltd. Vancouver, B.C.	$ 3.69/ 113 g	Jimmy's Chinese Style Beef Jerky is a sugar-cured jerky. The jerky is sliced very thin which makes the jerky lack chewiness.
Soo Singapore Jerky Ltd. Singapore	$ 3.99/ 113 g	This company produces beef jerky, pork jerky and fruit-flavored jerky. The pork jerky is not as hard as beef jerky and fruit-flavored jerky, and the texture was similar to our prototype vegetarian jerky. Thus, the pork jerky was used to compare with the prototype jerky during consumer testing.

physical and chemical bindings in the curd matrix of partially dried tofu are very weak; thus, the texture of the partially dried curd is crumbly.

To overcome the textural problems in some food analogues, e.g. immitation, engineered, or fabricated vegetarian products, two methods are generally used:

1. Addition of appropriate food ingredients or additives

Hydrocolloidal materials such as starches and gums have been added to the products to make the texture of the products firmer or more cohesive. A combination of modified starches and gums such as guar gum, carrageenan, algin, etc. have been used with some degree of success.

2. Utilizing a suitable texturization technology

To create structure in an otherwise pasty product such as mechanically deboned meat or soy protein paste, a texturization technology may be used. Freezing texturization, extrusion, and spinning technologies have been used to improve the texture of products made from these materials. However, although these methods have been shown to markedly improve textural properties of some products, they involve significant additional costs in terms of equipment and operation.

More recently, another method has been developed to impart structural properties to these engineered products. The method involves incorporation of natural food fiber into the products. Ooraikul *et al.* (1993) extracted fiber strands from rhubarb stalks and incorporated them into products such as hamburger, beef jerky, and chicken surimi. They reported improved sensory scores of the products with added rhubarb fiber. They also reported that rhubarb fiber has the ability to reduce total cholesterol, low-density lipoprotein (LDL), and triglycerides in animal and human subjects (Basu *et al.*, 1993; Ooraikul *et al.*, 1993; Goel *et al.*, 1997).

Thus, the use of rhubarb fiber as a texturizing ingredient in engineered food appears to provide two-fold benefits; i.e. improvement of textural quality and increase in nutritional value. For vegetarian products, it appears ideal that rhubarb fiber should be a material of choice for the improvement of their textural properties.

1.2. Objectives of the Project

The primary objective of this research was to develop a processing method to incorporate rhubarb fiber, binding, flavoring and coloring agents into tofu to produce some unique products such as vegetarian jerky and burger patty which are not currently available on the market. The relatively low cost prototypes would contain dietary fiber and have unique, chewy textures. Other properties of the products would include high levels of calcium, good source of protein with all the essential amino acids, and low in fat. Rhubarb fiber in the prototypes would provide additional health benefits to the consumers. Sensory, physical, chemical, microbial and economic characteristics of these products were also evaluated.

1.3. Literature Review

1.3.1. Demand for Vegetarian Products

Vegetarian products are usually consumed by four major groups of consumers: vegetarians, followers of some religions, health- or safety-concerned individuals, and economic- or ecologically–concerned individuals. In the following section, each of the four consumer groups will be discussed in some detail.

1.3.1.1. Vegetarianism

Vegetarianism was initiated in mid 500 B.C. by Pythagoras (582-500 B.C.), who was considered the "father of western vegetarianism". Since then, vegetarianism has spread to India, China, Italy, England and later in North America. In 1840s, vegetarian societies were established in England and grew rapidly. From the 18^{th} to 20^{th} century, vegetarianism expanded to North America. Most of the North American vegetarians were concerned about their health rather than about animal ethics at that time (Gregerson, 1992). The term "vegetarian" was established in 1847. It was derived from the Latin word "vegetus" which means whole, sound, fresh, and lively. In 1940's, the term "vegan" was adopted by the U.K. Vegan Society. Nowadays, there are vegetarians around the world. The distribution of North American and British vegetarians is summarized in

Table 1.4 (Gregerson, 1992; Stoneman, 1993; Realeat Survey, 1995; Vegetarian Resource Group, 1997; Toronto Vegetarian Association, 1997), and the major classes of vegetarians are listed in Table 1.5. The growing number of vegetarians, individuals who avoided red meat, and those who consumed less meat, are shown in Figure 1.1 (Realeat Survey, 1984-1993).

Vegetarianism is a growing trend in Canada (Schultz, 1996) and teenagers are the fastest growing group. A survey indicated that 28% of Canadian teenagers between 11-19 years of age considered vegetarianism as "trendy" in 1996, compared to 21% in 1991 (Teenage Research Unlimited, 1991; 1996). A similar trend was observed in the United Kingdom where it was estimated that about 8% of British teenagers between 11 and 18 years of age actively participate in vegetarian movement. Moreover, the Vegetarian of the United Kingdom persuaded 45% of the schools in the U.K. to provide students with at least a choice of vegetarian meal on the daily menu (Gregerson, 1992). There will likely be more vegetarians in the near future and the demand for vegetarian food will keep increasing. The food industry is responding by providing a variety of vegetarian products. There are also an increasing number of vegetarian magazines, supporting groups, and internet web sites. Being one of the largest fast food restaurant franchises, McDonald's also considered the growing number of vegetarian customers and set up a vegetarian product line in its restaurants in India (Stackhouse, 1996).

1.3.1.2. Personal Belief

Religions such as Buddhism and Seventh-Day Adventists promote vegetarianism. In Buddhism, cruelty is defined as the pleasure one obtains from the sufferings of others, including animals (Conze, 1975). Thus, Buddhism promotes a meatless diet which is considered a compassionate act. In 1850's, there was a hygienic movement among the Seventh-Day Adventists when they abandoned smoking and consumption of tea, coffee, and meat to adopt a "healthy" living (Olsen, 1972).

In addition to religion, the animal right movement also plays a role in the growth of vegetarian market. Many of the animal right activists oppose industrial farming because they believe that animals should have the right to live freely in the environment.

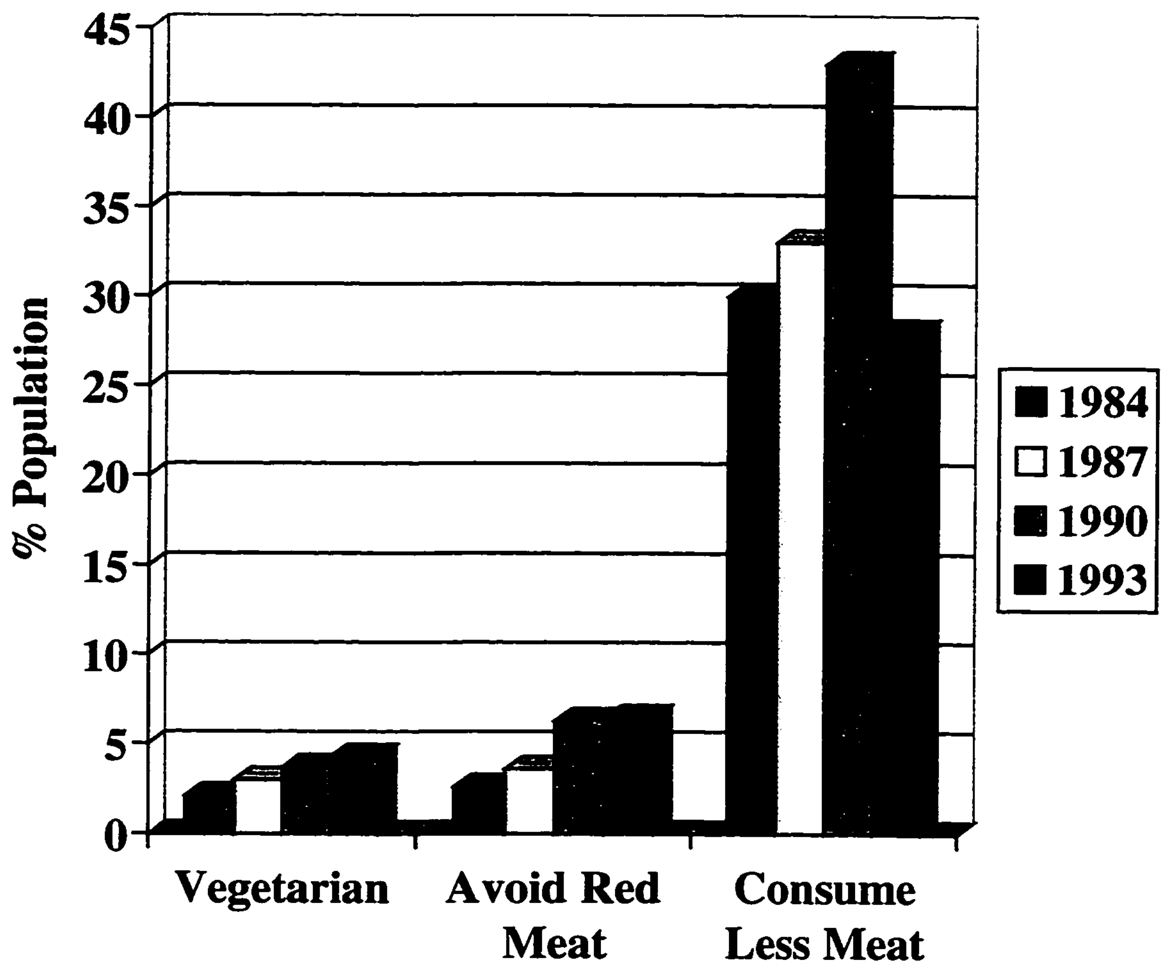
Table 1.4 - Summary of vegetarian distribution in North America and England

Country	Estimated Vegetarian Population (Year of Estimation)	Source	Remark
Canada	2% Population (1993)	Stoneman, 1993	2% of Canadian population did not consume red meat.
United States	• 7 to 9 Million (1992) • 0.3% to 1% Population (1994)	• Gregerson, 1992 • Vegetarian Resource Group, 1997	Two-thirds of the vegetarians considered animal rights as their reason to be a vegetarian
North America	5% Population (1996)	Toronto Vegetarian Association, 1997	2% Population were vegans
Britain	• 3.6 Million (7% Population, 1992) • 2.6 Million (4.5% Population, 1995)	• Gregerson, 1992 • Realeat Survey, 1995	• The estimate only included vegetarians who were members of vegetarian organizations. • The number of vegetarians, people who avoid red meat and people who consume less meat were increasing as shown in Fig. 1 (Realeat Survey, 1984-1993).

Table 1.5 – Classification of vegetarians

Vegetarian Category	Description
Lacto-ovo Vegetarians	Vegetarians who exclude all meat, but consume dairy products and eggs
Lacto Vegetarians	Vegetarians who exclude all meat and eggs, but consume dairy products
Vegans	Vegetarians who exclude all meat, eggs and dairy products and prohibit the use of animal products such as leather
Others Fruitarians	Vegans who do not consume plant parts that kill the plant (e.g. carrots and potatoes) but consume grains and fruits

Figure 1.1 – % British population of vegetarians, individuals who avoided red meat and individuals who consumed less meat between 1984-1993



Some of the books such as *A Diet for a Small Planet* (Lappe, 1975) and *Diet for a New America* (Robbins, 1987) caught the attention from animal right believers, vegetarians, health-concerned individuals as well as the National Cattlemen's Association (USA) which responded by publishing a book called *Current Issues in Food Production: A Perspective on Beef As A Component in Diets for Americans: A Scientific Response to John Robbin's "Diet for a New America"* (Cross and Byers, 1990).

1.3.1.3. Health and Safety Concern

With the growth of the economy, individuals have higher purchasing power and are more concerned about their health and the safety of the food they consume. Almost all the participants (97%) in a survey conducted by Food Marketing Institute indicated that they ensured themselves of having healthy diets by changing their eating habits (Food Marketing Institute, 1997). As a result, health claims are used as an advertising tool and the American food industry expected 75% of consumers being influenced by health claims (Hollingsworth, 1997). Health becomes one of the important requirements in consumers' mind. With regard to the health food market, the total market for functional foods in the United States was between US$ 7.5 - 9 billion in 1996 (Hasler, 1996), the Japanese functional food market was over US$ 3 billion in 1993 (Wrick, 1993), and the Chinese functional food market was approximately US$ 2.5 billion in 1996 (Dai and Luo, 1996). The demand for "healthy" food products is excellent.

The occurrence of cancer, cardiovascular diseases, osteoporosis, etc. has been related to diet. In the United States, the FDA has set up regulations on health claims such as calcium intake related to lowering risk of osteoporosis, fat intake related to heart disease, and dietary fiber intake related to reduced risk of cardiovascular diseases. It was estimated (in 1992 US dollars) that the direct health costs ascribed to meat consumption were $ 2.8 to 8.5 billion for hypertension, $ 9.5 billion for heart disease, $ 0-16.5 billion for cancer, $ 14.0-17.1 billion for diabetes, $ 0.2-2.4 billion for gallbladder disease, $ 1.9 billion for obesity-related musculoskeletal disorders, and $ 0.2-5.5 billion for foodborne diseases, making the total of $ 28.6-61.4 billion (Barnard *et al.*, 1995). Dwyer (1988) summarized extensive literature search regarding the health benefits of consuming vegetarian diets. Chang-Claude *et al.* (1992) conducted an 11 years follow-up study and found the mortality rate due to cardiovascular diseases, cancer, and digestive system diseases to be lower among vegetarians than non-vegetarians. These studies indicated the benefits of a balanced vegetarian diet. In a survey concerning food-related value orientations, attitudes and beliefs, more vegetarians were satisfied with their health status than non-vegetarians (Sims, 1978). Some health-concerned individuals consider consumption of vegetarian diet as a way to keep themselves healthy. It appears that the market for a well designed, healthy vegetarian product is enormous.

Some physicians considered the use of vegetarian diet to correct some of their patients' health problems. For example, a group of physicians assigned their patients to an experimental group (including a low-fat vegetarian diet, abandon smoking, stress management training, and moderate exercise without using lipid-lowering drugs) and reversed 82% of the coronary heart disease in the patients (Ornish *et al.*, 1990). Vegan diet is beneficial in that it has a high polyunsaturated fat/saturated fat ratio with very low cholesterol level, and the concentration of dietary fiber and plant sterols is high (Abdulla *et al.*, 1981). Vegetarian diets that are low in fat, low in saturated fat, low in cholesterol, but high in fiber were also found to lower blood pressure as well as reduce the risk of coronary heart disease and hypertension (Beilin, *et al.*, 1988). It is also less likely to find cancers in the large bowel, breast, and prostate among vegetarians (Phillips and Snowdon, 1983).

Obesity is a common health problem in developed countries which may be reversed by adopting vegetarian diets. A survey was conducted with 21,000 participants recruited from health food stores, vegetarian societies and health food magazines. Body mass index was highest among the meat eaters, lowest among the vegans and intermediate among fish eaters and vegetarians. 9.2% of the women and 6.4% of the men were clinically obese among the meat eaters (Anonymous, 1996).

Consumers search for health food with the hope that it can improve their health and prevent diseases, resulting in a rapid growth of health food market. Better nutritional education also promotes the consumption of fruit and vegetable products which contain vitamins, minerals and antioxidants. Thus, the market potential of vegetarian products, which are considered "healthier" by consumers, is excellent.

In addition to health concern, food safety concern is another reason for the growth of the vegetarian food trade. Consumers have a tendency to relate foodborne diseases with meat supply. In 1993, it was estimated that the occurrence of foodborne diseases caused by meat consumption was 59.6-69.7% of all the foodborne illnesses in the United States (Food Safety Inspection Services, 1993). Hamburger disease, *E. coli* contamination on meat, Salmonellosis, parasites in meat, etc. are some of the problems which have caught consumer's attention in recent years.

In the past few years, mad cow disease (Bovine Spongiform Encephalopathy) has become one of the major food safety concerns. Since the outbreak of the disease, the British beef industry has lost millions of dollars. Another incidence happened in Hong Kong in May 1997 where a child died from a new avion virus which also caused the death of 5 other people and infected a total of 18 people (Singtao Electronic News, 1998a; 1998b). The Hong Kong poultry industry has lost millions of dollars since the incidence. Other incidences involved the discovery of toxins in deep-sea fish which affected 80 people in Hong Kong (Singtao Electronic News, 1998b). These incidences have prompted consumers to reconsider their diets. Some have turned into vegetarian diet while some have decreased their meat consumption (Richardson, 1994; Richardson *et al.*, 1994) and increased their fruits and vegetable consumption.

1.3.1.4. Economic, Environmental and Ecological Factors

Economic, environmental and ecological concerns also affect the demand for vegetarian products. Yorks (1978) conducted a study and estimated that it required 2,200 to 16,000 kcal energy to produce 1 kg of meat and an extra 500 kcal to process it into a meat product, while soybean production required 950 kcal/kg, and 760 kcal/kg to produce a meat analogue. The more energy is used, the higher the production cost. Waste disposal from farm animals is one of the concerns for environmentalists, whereas ecologists are concerned with the disturbance of the ecological system of the farm and its surrounding area.

1.3.2. Texturization Technology

Between 1960's and 1980's, there were over 200 texturization techniques proposed (Giddey, 1983). Freezing texturization, extrusion, and spinning technology are three of the advanced techniques that have been used to improve the texture of food products.

Freezing texturization was developed by Menzi and Rufer (1981). The principle of freezing texturization is by forming a network of parallel channels on a half-frozen protein mixtures. Since slow-freezing results in formation of large ice crystals and concentrates the solids in cellular solution, protein forms bonding and produces a chewy product.

The principle of extrusion involves pressurizing and heating a mixture of protein, flavoring and coloring agents with an appropriate amount of water and extruding the mixture into the atmosphere. As water vaporizes, the extrudate expands and sets to form a texturized product (Ziemba, 1969; Harper, 1981).

Spinning technology was developed by Boyer (1954). The principle of spinning technology is by preparing the protein as an alkaline spinning "dope" which is then extruded through spinnerets into acid bath where the "dope" forms fibers which are then washed. The spun protein fiber is then mixed with binder and fat, and then flavoring and coloring agents are added to form into meat-like products.

The cost of the operation and equipment of the above three technologies is very high. The purpose is to form fibrous structures and make the final products chewier. A method that requires lower production cost while provides a chewy texture is thus favored. Rhubarb fiber, with its unique chewy fiber characteristics, is considered a good alternative.

Because of the unique characteristics of rhubarb fiber, it can be incorporated into food analogues to improve their textural and nutritional qualities. Ooraikul *et al.* (1993) incorporated rhubarb fiber in various products and claimed that the fiber-added products had superior texture to similar type of products which had no added fiber. Atapattu (1993) incorporated rhubarb fiber into mechanically deboned chicken meat to produce a chicken surimi product and found the fiber-added surimi to have better texture. Other products such as beef burger patty and beef jerky made with ground or deboned beef with added rhubarb fiber, have been proposed by Ooraikul *et al.* (1993).

1.3.3. Rhubarb

Rhubarb (*Rheum rhaponticum*) is a member of Buckwheat (Polygonaceae) family. It is an underutilized commodity but grows well in temperate or cold countries like Canada. In some countries such as Australia and the United States, rhubarb has been produced on commercial scale. The root of rhubarb (*Rheum officinale*) has been used by Chinese as laxative since 2700 B.C. (Hauser, 1991). In western countries, rhubarb stalks are usually used for making pies, jelly, jam, sauce and other desserts.

In recent nutritional and clinical studies, rhubarb fiber was shown to reduce total cholesterol, low-density lipoprotein (LDL), and triglycerides in both rats and human subjects (Basu *et al.*, 1993; Ooraikul *et al.*, 1993; Goel *et al.*, 1997). In 1997, 96.0 million American adults had cholesterol level over 200 mg/dL and 37.8 million American adults had cholesterol levels over 240 mg/dL, and 36.5% of American youth age 19 and below had serum cholesterol of 170 mg/dL or higher (Sloan, 1997a). Therefore, a natural way to lower cholesterol levels by adding dietary fiber such as rhubarb fiber in one's diet would be well accepted. In a survey by *the Prevention Index* (1996), 57% of the participants agreed that they attempted to intake more fiber. Moreover, low-fat diets which are rich in dietary fiber may also lower the risk of some types of cancer (Phillips and Snowdon, 1983; Giese and Katz, 1997). Therefore, the market for fiber-added products is promising.

Dried, grounded rhubarb fiber contains 8% soluble and 66% insoluble dietary fibers (Ooraikul *et al.*, 1993). In addition to its high fiber content, rhubarb fiber has a unique chewy texture and provides structural support for food products and improves their texture.

However, the oxalate content in rhubarb is relatively high which may influence calcium absorption as proposed by some researchers. Overconsumption of oxalate may lead to kidney stones or kidney failure for some individual. During World War I, rhubarb leaves which contain high levels of oxalate, were recommended as a food source in

Britain and caused many cases of poisoning (Robb, 1919). Whether or not oxalate in rhubarb stalks causes kidney stone and influences calcium absorption is still controversial. Some researchers believe that animal protein is one of the requirements for kidney stones formation in western societies (Robertson *et al.*, 1979a; Robertson *et al.*, 1979b; Breslau *et al.*, 1988; Kok and Papapoulos, 1993), and others believe that calcium absorption is not affected by consumption of rhubarb fiber at a 5% level (Goel *et al.*, 1996).

To date, there have been a few studies on product development using rhubarb stalk fiber (Atapattu, 1993; Ooraikul *et al.*, 1993; Cai, 1997). These studies include the development of beef burger patty, jerky, chicken surimi product, and quarg. Other products derived from rhubarb stalks, such as sweet and sour sauce, candies, toppings, beverages, etc., were also proposed.

1.3.4. Soybean Curd or Tofu

Soybean curd or tofu has been consumed by Chinese since 164 B.C. (Chen, 1989). It is the major source of calcium for Chinese. Calcium is important for the treatment of hypertension and prevention of osteoporosis, which affects 25 million Americans in 1997 (Sloan, 1997a). The total sale of calcium was US$ 349 million which made it the leader of mineral category in food, drug, as well as mass merchandise outlets, and its sale in health or natural food stores was US$ 180 million (Sloan, 1998). Calcium deficiency is one of the major concerns of the aging population. Instead of taking calcium pills, tofu is a good alternative source of calcium.

Tofu has been a popular food item for vegetarians. With extensive studies on the health benefits from soy consumption, many health-concerned individuals have increased their consumption of tofu products.

Tofu is a good source of phytoestrogen, which is considered a natural substitute for estrogen for women who suffer from menopausal symptoms and reduces the risks of cancer and some hormone-dependent diseases such as breast and prostate cancers (Adlercreutz *et al.*, 1992; Dwyer *et al.*, 1994; Messina *et al.*, 1994; Messina and Messina, 1997). It was estimated that 35 million American women suffered at least one menopausal symptom in 1997, but only one-quarter of the patients purchased the prescribed estrogen (Sloan, 1997a). Since tofu contains a high level of phytoestrogen, it can be consumed to provide a natural cure. Tofu is also a good source of protein, and if consumed together with wheat products, it can provide all the essential amino acids one needs. Tofu is bland in flavor and, therefore, it may be used to make desserts such as tofu "ice-cream", tofu "milkshake", or main dishes such as grilled tofu, barbeque tofu, etc.

The gelation mechanism of tofu consists of protein denaturation and hydrophobic coagulation. The hydrophobic regions of protein molecules, which are located in the molecule at normal state, are exposed to the outside by heat denaturation (Koshiyama *et al.*, 1981; Matsudomi *et al.*, 1985). The denatured soy protein which is negatively charged above isoelectric point (Kohyama and Nishinari, 1993) is neutralized with the presence of coagulating agent, e.g. calcium ions, and a strong bonding is formed.

Tofu of different textures can be made by adjusting the amount of coagulating agents used and the degree of pressing accomplished after protein coagulation (Snyder and Kwon, 1987). The texture of tofu ranges from silken (very soft) to soft, medium, firm and extra firm. To date, there is no regulation on the texture of tofu in Canada.

There are a few types of coagulants used in tofu making. One of them is gypsum powder ($CaSO_4$) which was found to be superior to other calcium salts (Tsai *et al.*, 1981; Wang and Hesseltine, 1982). If too little gypsum powder is added to soymilk, soy protein will not curdle completely. By adding more gypsum powder, a soft curd will form. When even more gypsum powder is added, the curd will be harder and lighter in weight.

1.3.5. Binding agents

Binding agents such as food gums, starches, and gluten are commonly used in restructured products. They act as an adhesive to bind ingredients together. Some fruit leather and some commercial vegetarian burger patties contain food gums and modified starches. In traditional Chinese vegetarian food and in some commercial products, wheat gluten is used as the major binding ingredient.

Food gums are derived from seeds, plant extrudate, seaweed, or microbial excretion. Some of these food gums are very sticky, some are slimmy, while others form chewy gels. Examples of food gums are carrageenan, guar gum, and algin. Each of the gums has different textural/functional characteristics, but some of them have an aftertaste, like carrageenan.

Starches are insoluble in water, but after they are heated with water, they gelatinize and starch granules expand. When the gelatinized starch cools down, a gel is formed. The gel may be opaque, chewy, or pasty depending on the type of starch. Some commonly used starches are corn starch, tapioca starch, potato starch, etc. Starches can be modified to alter their functional properties.

Wheat gluten was isolated by Beccari (1745). Gluten proteins consist of gliadin and glutenin. Gliadin contributes to the extensibility while glutenin contributes the elasticity of the mixture. Glutenin contains a high proportion of hydrophobic amino acids such as leucine which promotes hydrophobic interactions. Glutenin also contains a high proportion of glutamine which promotes hydrogen bondings (Khan and Bushuk, 1979). With the presence of water, gluten proteins hydrate and interact with each other and with other components to form a complex. Sulfhydryl group bonds with other sulfhydryl group to form disulfide bonds (Ewart, 1977). This type of binding is very strong and can withstand a high degree of stretching. Gluten is one of the strongest binding agents and is used in some of the commercial vegetarian products and in traditional Chinese vegetarian food.

CHAPTER 2
PRODUCTION AND SENSORY EVALUATION OF THE PROTOTYPE JERKY AND BURGER PATTY

2.1. Introduction

Based on the promising market potential of vegetarian products and the functional and nutritional benefits from the addition of rhubarb fiber, the focus of this research was, therefore, on the development of meat-like products with improved texture. An initial attempt was made to incorporate both rhubarb juice and fiber into soymilk as coagulants and as texturizing agents, in the hope that the fiber would distribute evenly in the curd. However, because of some technical problems which resulted in improper coagulation of soy protein, the method was abandoned and only pressed rhubarb fiber and other ingredients were added to tofu after it had already been made with $CaSO_4$ as the coagulant. The goal was to produce vegetarian jerky and burger patty. When the prototype jerky and burger patty were formulated, some vegetarians and some non-vegetarians were recruited for focus group discussions. Their comments were used to improve the formulations and the production process. Consumer acceptance test and objective texture measurement of the samples were conducted, comparing the prototype products with commercial products.

2.2 Preliminary Work

2.2.1. Attempts at the Incorporation of Tofu and Rhubarb Fiber and Juice as Coagulant in Tofu Production

Tajiri (1993) conducted a study using citrus fruit juice as the coagulating agent in the production of tofu. Thus, at the beginning of this study, rhubarb juice, together with the fiber were added to soymilk as a coagulant. Frozen stalks were deskinned, steam blanched, rolled and beaten in wash water. The fiber, together with the washing and the juice was added to soymilk that has been heated to $98 \pm 1^{\circ}C$ and then held at $95 \pm 1^{\circ}C$ for 5 min as described in Section 2.3.2. The amounts of ingredients used are shown in Table 2.1. The soy protein curdled immediately, but the yield of the soy curd was much lower

Table 2.1 – Formulation for the rhubarb-coagulated soy curd

Ingredient	Amount Used, g
Frozen Rhubarb Stalk	800.0
Soybeans	365.0
Water	1400.0

than that of the $CaSO_4$-coagulated soy curd. Some soy curd partially coagulated on the rhubarb fiber strands. The rhubarb-coagulated soy curd was more fragile and less flexible when compared with the $CaSO_4$-coagulated curd. Since the curd was very sour, less stalks were used, which resulted in a non-cohesive curd. Thus, gypsum powder was added to aid the coagulation. However, the resulting curd was not cohesive enough and rhubarb fiber was not distributed evenly in the curd. That was because $CaSO_4$ required longer coagulation period during which the fiber descended to the bottom. To improve the distribution of the fiber, Certo pectin (Kraft Canada Inc.. ON.) was added to increase the viscosity of soymilk and it made rhubarb fiber distributed more uniformly in the curd. The curd was slightly sour, flexible and hard. After cooling, the curd was inelastic and broke into pieces. The amounts of ingredients added are summarized in Table 2.2. Flavoring was added to soymilk together with rhubarb juice and fiber as well as gypsum powder in an attempt to mask the sourness. The resulting curd was sour but otherwise flavorless because the flavoring agent was lost during whey draining, which indicated that the flavoring agent did not react with the soy curd. Therefore, it was decided that flavoring should be added after whey had been drained out, by mixing it together with other ingredients. As a result of this preliminary work, it was found that soy curd coagulated with rhubarb juice and with added flavor (whey not being drained out) may be consumed as a non-dairy "yogurt" product, but the fiber has to be cooked and pureed to increase the smoothness of the final product.

2.2.2. Use of Binding Agent

Since tofu, rhubarb fiber, flavoring and coloring agents had to be mixed and bound together to form a cohesive product, a binding agent was required. Thus, hydrocolloidal ingredients such as starches and gums were added. The criteria for choosing the binding agents were to select the ones that did not give strong aftertaste or other unpleasant odor, but would make the final products cohesive. From all the starches, food gums and wheat gluten tried, the best were wheat gluten (Canasoy Enterprises (Canada) Ltd., Vancouver, B.C.) and Redisol 4 (pregelatinzed tapioca starch, A.E. Staley Manufacturing Company, Decatur, IL). For the burger patty formulation, Redisol 4

Table 2.2 – Formulation for the modified rhubarb-coagulated soy curd

Ingredient	Amount Used, g
Frozen Rhubarb Stalk	800.0
Soybeans	365.0
Water	1400.0
Gypsum Powder	8.0
Certo Pectin	30.0

pregelatinized starch and wheat gluten were suitable binding agents. However, wheat gluten was the only suitable binding agent for the jerky formulation because other binding agents were not strong enough to sustain physical disturbances during the production process, and cracks formed on the surface of the jerky. Wheat gluten has another advantage over the other binding agents, and was chosen for the two prototypes. The choice was made for nutritional reasons since soy protein lacks sulfur-amino acids but has a high concentration of lysine, whereas wheat is low in lysine but is high in sulfur-amino acids. Thus, soy and wheat proteins make a good nutritional combination which would provide the products with all the essential amino acids.

2.2.3. Incorporation of Rhubarb Fiber to Tofu After Soy Whey Draining

Two products were made: vegetarian jerky and burger patty. In the production of the jerky, tofu was crushed and mixed with the jerky flavoring and coloring agents and then wheat gluten was added to the mixture. The mixture was portioned and rolled into protein sheets between which a layer of fiber was placed as shown in Figure 2.1. The jerky was then dried as described in Section 2.3.2.

For the production of burger patty, tofu and rhubarb fiber were mixed with the burger patty flavoring and coloring agents. Since the acid in rhubarb fiber made the final products unpleasant in taste, the fibers were treated slightly. The treatment will be discussed in Section 2.3.2 and in Figure 2.5. Wheat gluten was added, mixed, and the mixture was weighed before molding in a hamburger patty press.

2.2.4. Focus Group Discussion

Vegetarians are the target users of the prototype products. However, non-vegetarians who are concerned with their health or have strong ethical beliefs may also be potential users. Thus, two focus groups were used: vegetarians and non-vegetarians. The prototypes were compared with controls which were made without added rhubarb fiber to determine if rhubarb fiber improved the texture and other attributes of the products. The compositions of the samples are shown in Tables 2.3 and 2.4 and the processing methods are discussed in Section 2.3.2.

Figure 2.1 – Schematic diagram of jerky with one layer of fiber

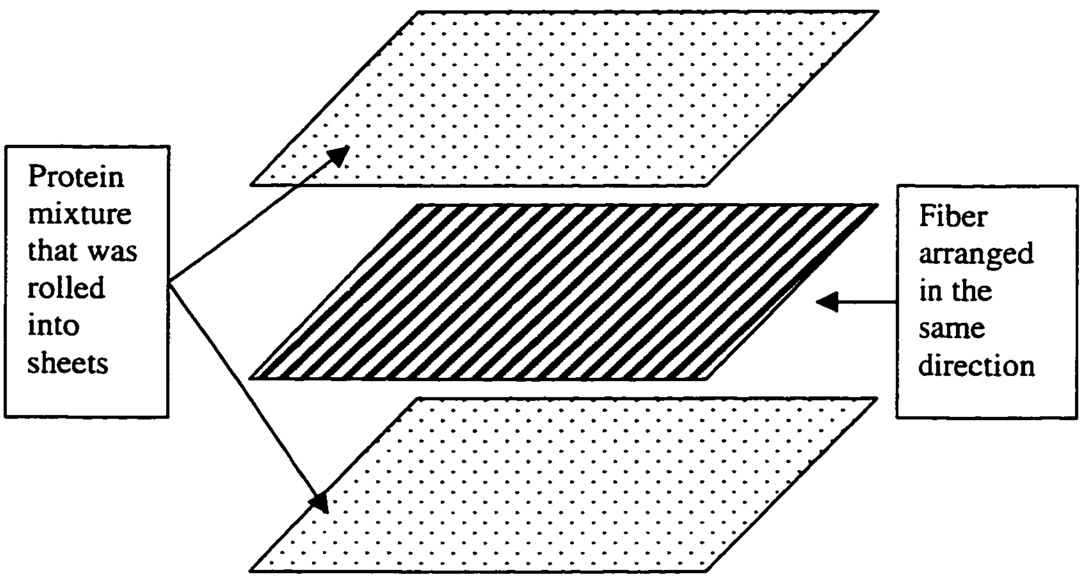


Table 2.3 – Jerky formulation for the focus group discussion

Ingredient	Jerky With Fiber, %w/w (Fresh Weight Basis)	Jerky Without Fiber, %w/w (Fresh Weight Basis)
Rhubarb Fiber	46.3 %[a]	0 %
Tofu	38.7 %	81.7 %
Corn Syrup	5.1 %	5.1 %
Soy Sauce	3.3 %	3.3 %
Wheat Gluten	3.1 %	6.4 %
Beefsate 4 Flavor	1.5 %	1.5 %
Caramel Color	0.51 %	0.51 %
Beet Powder	0.51 %	0.51 %
Black Pepper	0.31 %	0.31 %
Garlic Powder	0.20 %	0.20 %
Onion Powder	0.20 %	0.20 %
Paprika	0.12 %	0.12 %
Coriander	0.09 %	0.09 %
Ground Ginger	0.06 %	0.06 %
Total Weight	100 %	100 %

[a] 180 g of rhubarb fiber was obtained from 600 g of frozen rhubarb stalk

Table 2.4 – Patty formulation for the focus group discussion

Ingredient	Burger Patty With Fiber, %w/w (Fresh Weight Basis)	Burger Patty Without Fiber, % w/w (Fresh Weight Basis)
Rhubarb Fiber	34.1 %[a]	0 %
Tofu	41.0 %	66.3 %
Wheat Gluten	14.6 %	23.4 %
Soy Sauce	7.7 %	7.7 %
Beet Powder	0.78 %	0.78 %
Caramel Color	0.97 %	0.97 %
Garlic Powder	0.38 %	0.38 %
Onion Powder	0.38 %	0.38 %
Ginger Powder	0.09 %	0.09 %
Total Weight	100 %	100 %

[a] 35.0 g of rhubarb fiber was prepared from 115 g frozen rhubarb stalk

Results from focus group discussions showed most of the participants who tasted the jerky indicated that they preferred the jerky with fiber because they enjoyed tearing the jerky apart and noticing the fibrous structure which was similar to real meat jerky. They liked the appearance of the jerky very much but would prefer the color to be lighter. Not many participants could detect "beany" flavor from the prototypes which suggested that hot grinding of soybeans was able to minimize the off-flavor. Many of them preferred the odor of the jerky with fiber because they liked rhubarb very much. The participants wanted the jerky to be saltier. The vegetarians preferred the jerky to be spicier and suggested the use of chili pepper and smoke flavor as well as increasing the sweetness of the jerky. Since vegetarians do not consume meat products, they use spices to compensate for the missing flavor. The panelists found the texture of the jerky with fiber better because it was harder and chewier than the control without the fiber. Furthermore, the jerky with fiber was more flexible. However, they preferred it to be harder. Thus, some trials were made with thicker jerky with one layer of fiber and also jerky that was made by increasing the number of protein and fiber layers, while keeping the ingredient composition the same. Drying of the thicker jerky was very difficult. The jerky with 4 fiber layers in which each layer of fiber was perpendicular or parallel to the adjacent fiber layer (Figures 2.2 and 2.3) was harder and have an acceptable chewiness. The jerky with fiber layers perpendicular to the adjacent fiber layer was superior to the one with parallel fiber because the latter could only withstand pressure from one direction. The jerky sometimes split into two during the production if the jerky was picked up along the fiber direction.

The appearance of the burger patty was attractive as described by the participants, but they preferred the color of the burger patty to be lighter. The vegetarians enjoyed the flavor of the burger patty because it was a little spicy, but they preferred it to be spicier and less salty. On the other hand, non-vegetarians found the burger patty too spicy. The participants opined that the burger patty without fiber was too rubbery, and the rubberiness of burger patty was reduced by the presence of rhubarb fiber. The participants commented that the burger patty with fiber was soft because it had too much

Figure 2.2 – Schematic diagram of jerky with 4 layers of fiber (fiber layer arranged perpendicular to the adjacent layer)

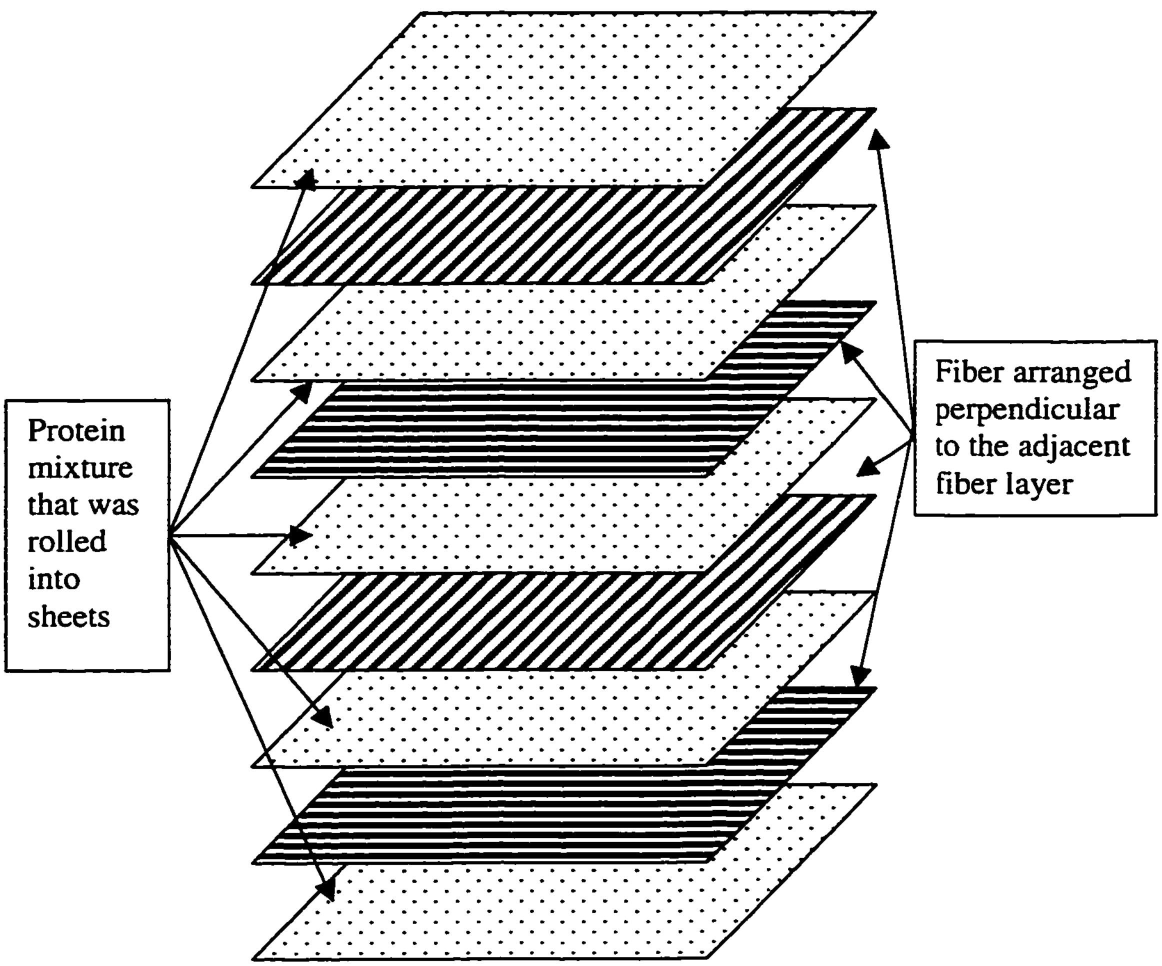
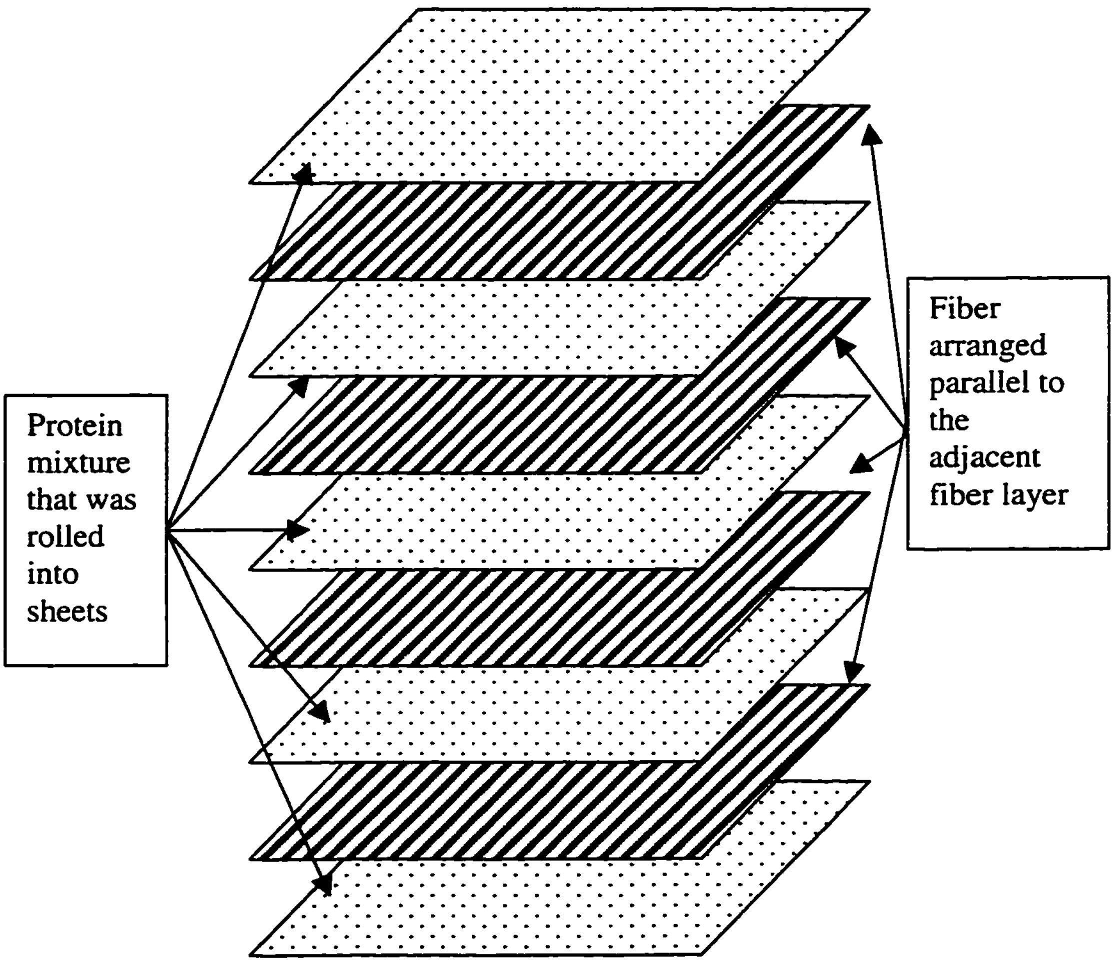


Figure 2.3 – Schematic diagram of jerky with 4 parallel fiber layers



moisture. Thus, the moisture of the fiber should be minimized before adding to the burger patty. Overall, they preferred the burger patty with fiber.

Results of the focus group discussion also indicated that the vegetarians are continuously searching for new products designed specifically for them, especially the vegans. They were enthusiastic and well motivated by the taste test. Most of the participants liked the products with added fiber. The market potential of the prototypes appears to be significant. It was revealed that they were searching for "food-on-the-go" that are nutritious and tasty. Most of them indicated that they liked the jerky with fiber and showed that they would like to have such a product on the market. They needed very flavorful and spicy food to compensate for the meaty flavor in a meatless diet. The jerky has to be spicier and sweeter than the test samples. Chili pepper was suggested as an additional ingredient. Since long fiber tended to pull out in long strips as the product was consumed, rhubarb fiber had to be cut into 1 cm instead of 6-8 cm for jerky production. For the same reason, the fiber used for burger patty production was cut shorter than 1 cm rather than 2-3 cm. Overall, they enjoyed the flavor of the prototypes with added fiber and some participants even requested more samples as their snacks. The fiber used in the burger patty had to be pressed before steaming to reduce the amount of water so that the burger patty would be firmer. Smoke flavor may be added to both products. Overall, the focus group discussion was informative and useful. The response was positive.

2.3. Materials and Methods

Whole soybeans (W.G. Thompson & Son Ltd., Blenheim, ON.) were purchased from a local tofu factory. Gypsum powder (Tak Cheong Co. Ltd., Hong Kong) was purchased from a local supermarket. Silicone type antifoaming agent (SAG 5693, 0.17 g for 1 L of soymilk) was supplied by OSI Specialties, Inc. (Endicott, NY). Filter cloth designed for tofu making was supplied by Tai Chung Tofu Factory (Taiwan). Rhubarb stalk was obtained from a local garden, trimmed and stored in a walk-in freezer (-30°C). The flavorings were supplied by UFL Foods (Edmonton, AB.). Empress Spices (Lucerne Foods Ltd., Vancouver, B.C.), China Lily soya sauce (Lee's Food Products Ltd., Toronto, ON.), No Name corn syrup (Toronto, ON.), and Woodland natural hickory liquid smoke flavor (National Importers Ltd., New Westminister) were purchased from local supermarkets. Wheat Gluten was obtained from Canasoy Enterprises (Canada) Ltd. (Vancouver, B.C.).

2.3.1. Formulation of Prototype Jerky and Burger Patty

Flavoring samples were obtained from two companies. Beefsate 4 from UFL Foods (Edmonton, AB.) was chosen because the taste was smoother than the others. The jerky flavor combination was modified from Proctor and Cunningham (1986) and the burger patty flavor combination was modified from Huffman and Cordray (1985).

To obtain a uniform product color throughout the study, caramel color and beet powder (UFL Foods Ltd., Edmonton, AB.) were used. The formulations of the improved jerky and burger patty are shown in Tables 2.5 and 2.6.

2.3.2. Processing Procedures

The tofu-making method used throughout the study was modified from Bumgamer (1976) and the advice from Goh (1996). Since soybeans contain lipoxygenase which produces a "beany" flavor when soybean is pureed and the enzyme is exposed to oxygen, hot water grinding (Wilkens *et al.*, 1967) was adopted to partially inactivate the enzyme. Lipoxyenase can be inactivated at temperatures above 80°C (Chen, 1989). After 3 min of pureeing, the mixture was at 74 ± 1°C; however, the "beany" flavor was significantly reduced as determined by the focus group. Some of the focus group members were not certain that the products were made of tofu. Therefore, hot water grinding of soaked soybean was effective in minimizing the "beany" flavor.

Because of the presence of lecithin in soybeans, foam forms during tofu making process. Therefore, an antifoaming agent was required to reduce excess foam formation. An antifoaming agent (SAG 5693) from OSI Specialties Inc. (Endicott, NY) was used throughout the study. Other antifoaming agents such as oil may also be used, but it would increase the lipid content of the final products.

Table 2.5 – Improved formulation for the jerky used in consumer testing

Ingredient	% w/w, Fresh Weight Basis
Tofu	45.0 %
Rhubarb Fiber	30.0 %
Corn Syrup	9.0 %
Wheat Gluten	6.0 %
Soy Sauce	4.7 %
Beefsate 4 Flavor	1.7 %
Black Pepper	0.60 %
Beet Powder	0.60 %
Smoke Flavor	0.60 %
Garlic Powder	0.40 %
Chili Pepper	0.31 %
Onion Powder	0.31 %
Coriander	0.25 %
Paprika	0.25 %
White Pepper	0.16 %
Ginger Powder	0.12 %
Total Weight Before Drying	100 %

Figure 2.6 – Improved formulation for the burger patty used in consumer testing

Ingredient	% w/w, Fresh Weight Basis
Tofu	46.8 %
Rhubarb Fiber	24.9 %
Wheat Gluten	17.9 %
Soy Sauce	5.4 %
Beefsate 4 Flavor	1.0 %
Garlic Powder	0.89 %
Caramel Color	0.80 %
Beet Powder	0.60 %
Onion Powder	0.30 %
Black Pepper	0.30 %
Coriander	0.30 %
Paprika	0.30 %
White Pepper	0.30 %
Ginger Powder	0.21 %
Total Weight	100 %

Soybean (365 g) was soaked in 2 L of water for 20 hours at room temperature (23°C). The soaked soybean was drained and pureed in 1.25 L of boiling water with 1.0 g of antifoaming agent for 3 min using an Osterizer mixer (Sunbeam Corp. (Canada) Ltd.). Meanwhile, 1.25 L of water was boiled and the puree was added to the boiling water and heated to 95 ± 1°C with occasional stirring. The puree was then filtered through 4 layers of cheesecloth. The filtrate (soymilk) was heated to 98 ± 1°C, then, the heat was reduced to 95 ± 1°C where it was held for 5 min. A mixture of 500 mL of water and 11.7 g of gypsum powder was added to the soymilk and stirred for 10 sec. The coagulation temperature was at 76 ± 1 °C. After 15 min, the soy curd was transferred onto cloth supplied by Tai Chung Tofu Factory (Taiwan) for whey draining and then pressed in a screw press for 1 ½ h. The tofu-making procedure is summarized in Figure 2.4.

To increase the production yield, dehulled soybeans may be used. Unfortunately, there was no dehulling machine available at the university; hence, whole soybeans were used throughout the study.

To eliminate the gritty texture, the skin of the rhubarb stalks was removed. The best method to remove the skin was to dip the frozen stalk in tap water and rub the skin off immediately. Since a thin layer of the skin was thawed while the rest of the stalk remained frozen solid, the skin was easily removed without pulling off the fiber strands. Lye peeling may also be considered in industrial production (Ooraikul *et al.*, 1993).

Steam and microwave blanching of rhubarb stalks were suggested by Ooraikul *et al.* (1993). Steam blanching was used throughout the study because it provided more uniform results. To separate the fiber, combing of the stalk fiber after steam blanching for 90 sec was investigated (Ooraikul *et al.*, 1993), but it resulted in a lot of broken fiber and the fiber was not separated uniformly. Therefore, pressing and rolling of the stalk was investigated. Rhubarb stalks were cut into 6 to 8 cm long for jerky and 2 to 3 cm long for burger patty and were rolled slightly (4 mm thick) after the skin removal. The pressed stalks of uniform thickness were steamed for 2 min and rolled to separate the fiber. This resulted in less broken fiber. Since part of the clear juice was pressed out, the stalks contained less acid, thus reducing the sourness of the final products. However, the stalks were still quite acidic and had a high moisture content, as indicated by the focus group. The processing procedure is summarized in Figure 2.5.

Figure 2.4 – Process flowchart of tofu making

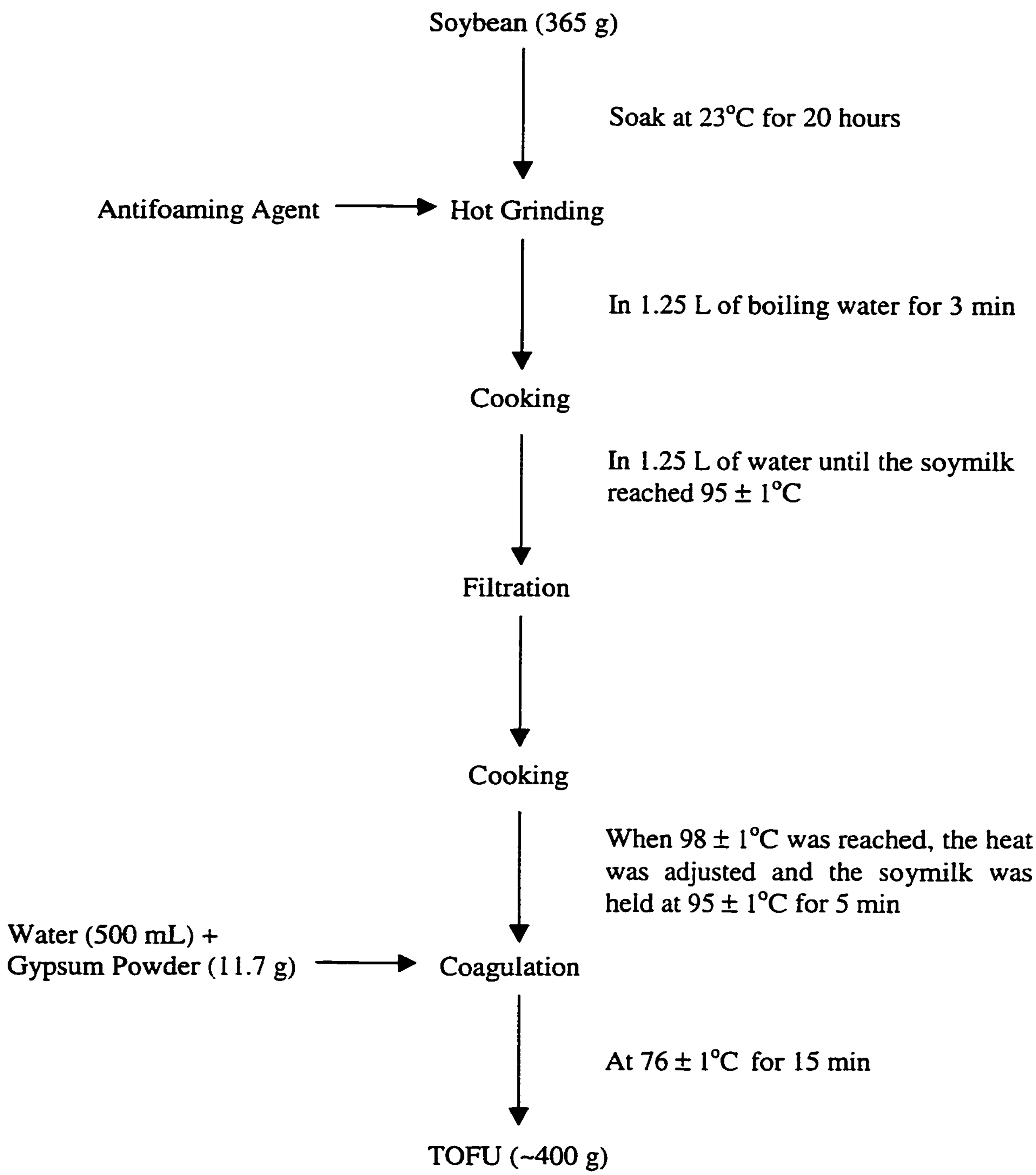


Figure 2.5 – Processing of rhubarb fiber for focus group discussion

Frozen Rhubarb Stalk (700 g)

↓

Dipping in Tap Water

↓

Skin Removal

↓

Thawing

↓

Rolling

↓ The stalks were rolled to 4 mm thick

Cutting

↓ 6 to 8 cm for jerky and 2 to 3 cm for burger patty

Steaming

↓ For 2 min

Rolling

↓

Separated Rhubarb Fiber (~200 g)

Since the focus groups suggested a drier product (especially the burger patty), the stalks were sliced (2 to 3 mm thick) to increase the surface area for leaching the acid, and the sliced rhubarb stalks were pressed for 15 min with a screw press to remove most of the juice. The pressed stalks were then soaked in tap water for 10 min and pressed for another 15 min. The steaming period had to be increased to 10 min. This method removed most of the acids from the stalk fiber and the resulting fiber was only slightly sour. In addition, the method minimized the differences among individual stalks due to non-uniform thickness, or from the difference in the catch-up time in the short steaming period (the steaming period was increased from 2 min to 10 min). The fiber for the jerky was cut into 1 cm and that for the burger patty was cut into less than 1 cm. The processing procedures of the rhubarb fiber used in jerky and burger patty are shown in Figure 2.6. The processing of rhubarb fiber for the jerky was designed differently from that for the burger patty to make it more convenient to layer the fiber during the production of jerky. Tofu, gluten, and rhubarb fiber were bound together and formed into the products as shown in Figures 2.7 and 2.8.

In order to minimize the differences between the prototype jerky and the commercial meat jerky used in consumer testing, a layer of corn syrup was basted on the dried prototype jerky and dried for an additional 30 min to make the surface of the prototype jerky glossy.

2.4. Sensory Evaluation of Prototype Jerky and Burger Patty

2.4.1. Background on Sensory Evaluation

Since tofu-based vegetarian products with added rhubarb fiber are new to the consumers, consumer acceptance test of the prototypes was conducted using both vegetarians and non-vegetarians. For the vegetarians, the prototype products were compared with the commercial vegetarian products. For the non-vegetarians, the prototype products were compared with commercial vegetarian products and meat products to determine the acceptability of both the prototype products and the commercial products. Three sessions of sensory testing were conducted. The first session

Figure 2.6 – Processing of rhubarb fiber for jerky and burger patty used in consumer testing

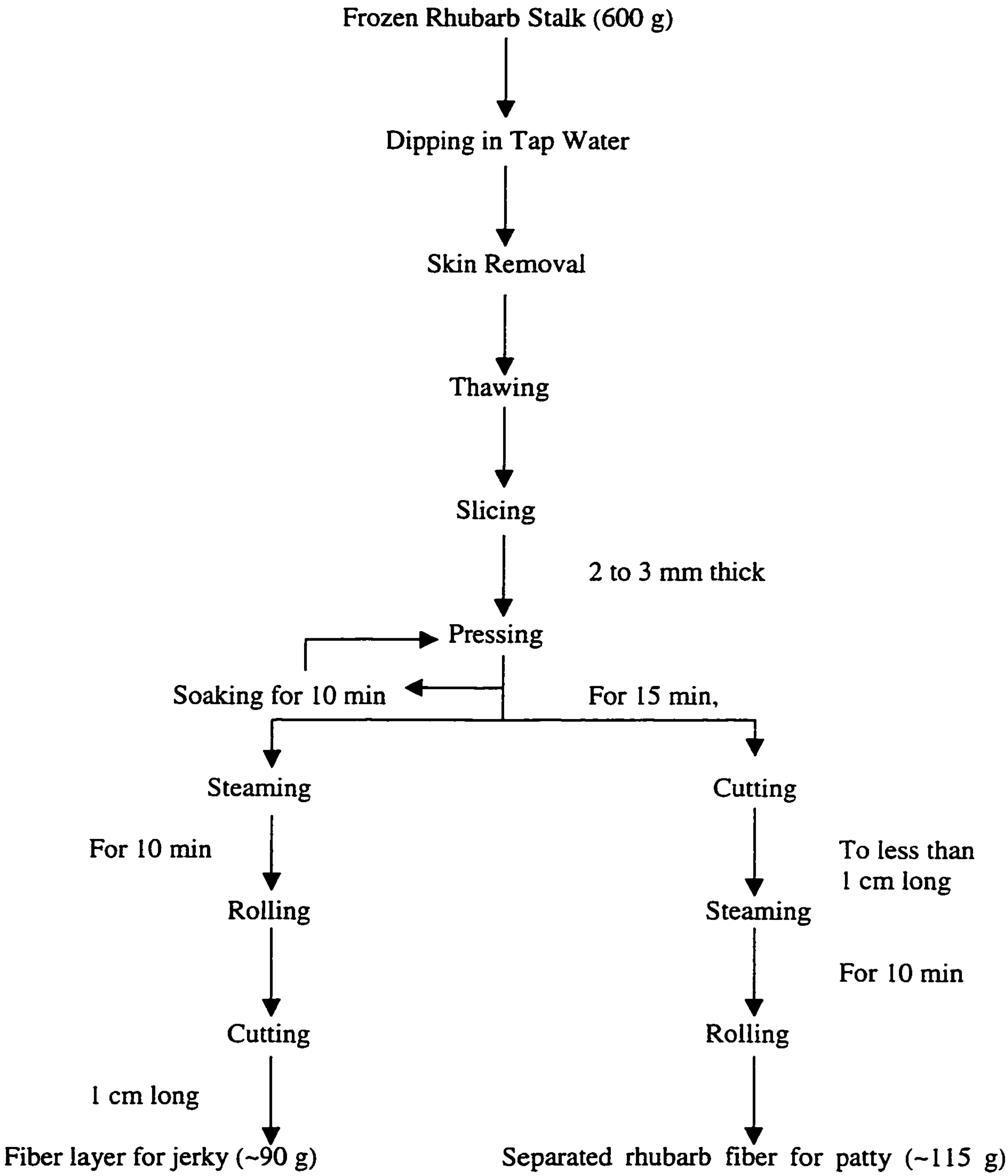


Figure 2.7- Process flowchart of prototype jerky

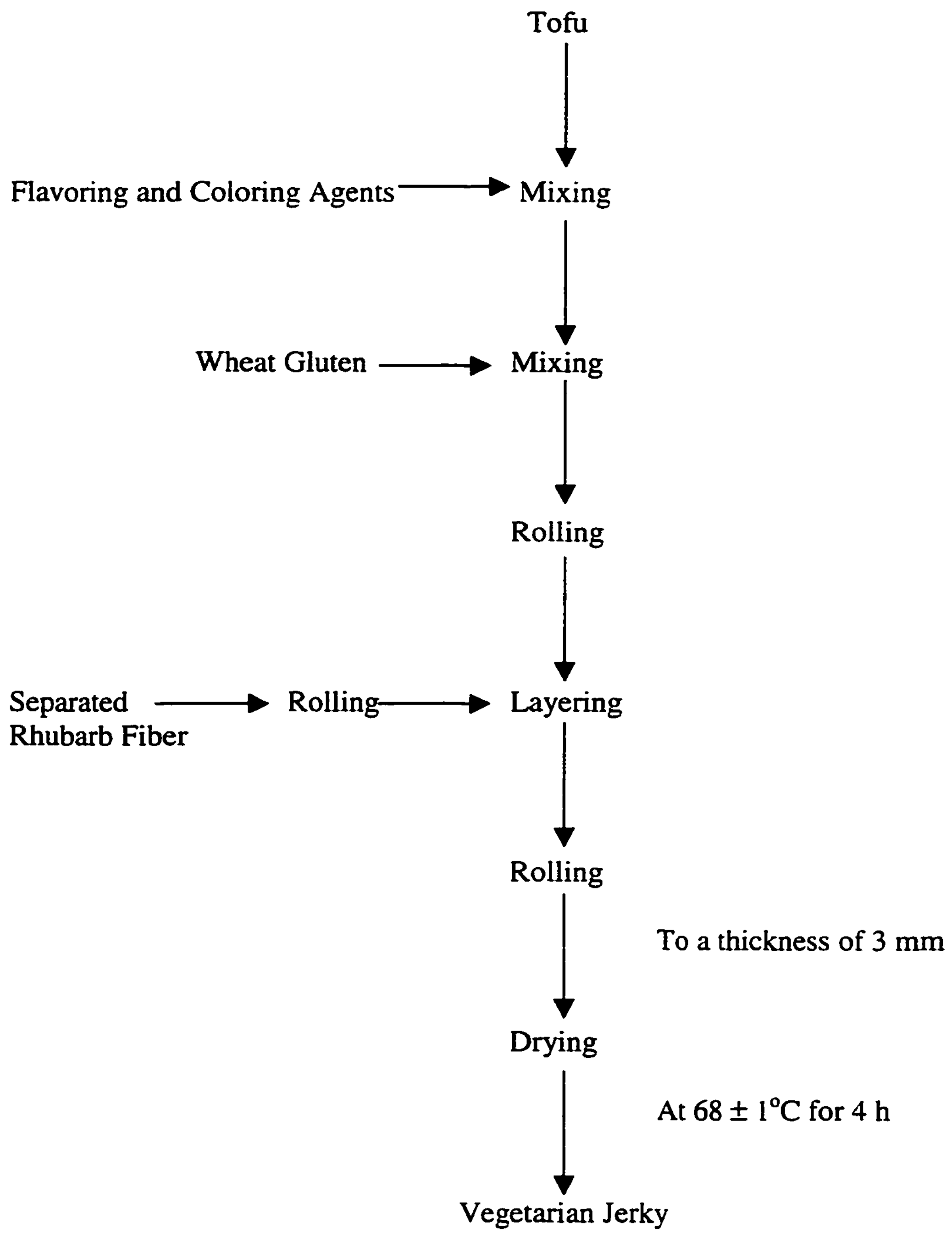
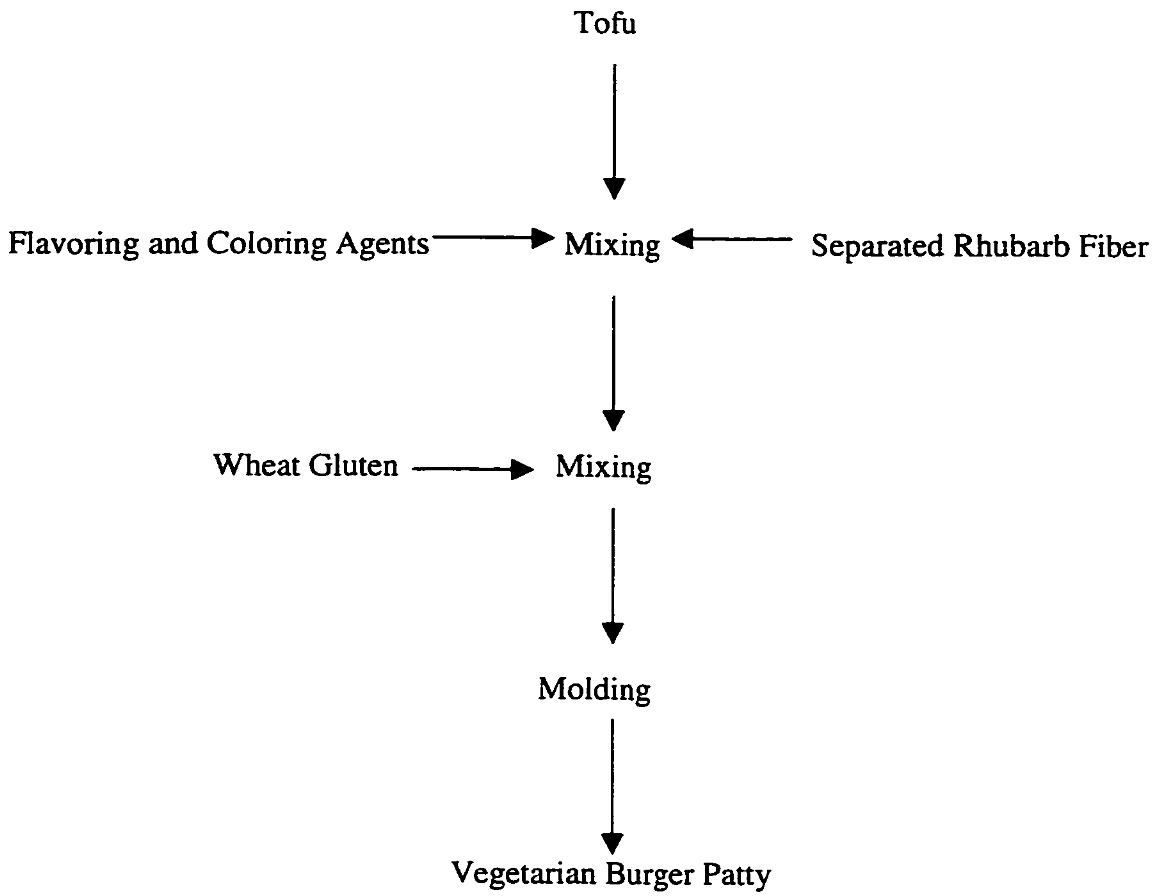


Figure 2.8 – Process flowchart for prototype burger patty



was on jerky-type products, the second session was on burger patties, both with non-vegetarians; and the third session was on the two prototypes with the vegetarians.

2.4.2. Test Environment

A booth was set up in the Student Union Building at the University of Alberta, and another at a vegetarian meeting to attract general public for their opinions. The participants were untrained panelists. The taste testing was performed under normal lighting.

2.4.3. Preparation of Samples

Commercial products were purchased from local supermarkets. The commercial vegetarian jerky used in the taste testing was Ta Brook dried beancurd (Jin Mei Shian Co. Ltd., Taiwan) and the commercial vegetarian burger patty used were Yves Veggie Cuisine Garden Burgers (Vancouver, B.C.) and Sunrise Tofu Patty (Vancouver, B.C.). The pork jerky used was produced by Soo Singapore Jerky Ltd. and the beef burger patty was purchased from Canada Safeway Ltd. Yves burger patty and Sunrise tofu patty will be called "commercial vegetarian burger patty 1" and "commercial vegetarian burger patty 2", respectively in this report.

The prototype jerky and the pork jerky were cut into 2×3 cm, and the vegetarian jerky was cut into 2.5×2.5 cm. They were wrapped in aluminum foil and were served at room temperature. All the burger patty samples were cooked at 177°C for 20 min. The samples were refrigerated after cutting into 1.5×1.5 cm and were wrapped in aluminum foil. Before sensory testing, the burger patty samples were placed in casserole dishes with lids, and were heated on hot plates for 1 h. The aluminum foil prevented moisture loss from the burger patties. All samples were coded with three-digit random numbers.

2.4.4. Evaluation Form

The product evaluation form and questions regarding personal information are shown in Figure 2.9.

Figure 2.9 – Sensory evaluation form

PERSONAL INFORMATION

Name:

Age: _____ below 10 _____ 10 - 19 _____ 20 - 29
_____ 30 - 39 _____ 40 - 49 _____ 50 - 59
_____ 60 - 69 _____ 70 - 79 _____ 80 or above

Gender: ________ Female
________ Male

Are you a vegetarian?
_____ Yes, which type? Lacto-vegetarian ______
Lacto-ovo-vegetarian ______
Vegan ______
Others, please specify: ______________
_____ No, I'm not a vegetarian.

Regularity of consuming the following products:

Frequency	Tofu	Jerky-type Products	Vegetarian Products	Meat
None				
Light (1-4 times/month)				
Moderate (1 to 6 times/week)				
Heavy (1 or more times/day)				

What do you expect from a vegetarian product?

Why do you consume jerky-type products/ Why you don't consume jerky-type products?

Questionnaire

Please grade the characteristics of the samples according to the scale below:

1 Very Unacceptable ← 2 — 3 — 4 — 5 — 6 — 7 — 8 → 9 Very Acceptable

Characteristics	*Sample No.*	*Sample No.*	*Sample No.*	*Sample No.*
Appearance				
Odor				
Flavor				
Texture				
Overall Rating				
Comments				

2.4.5. Sensory Procedures

The participants were asked to taste the products following the sequence indicated on the questionnaire. The panelists were instructed to rinse their mouth with water between samples.

2.4.6. Analysis of Score Sheets

Analysis of variance of the sensory results (combinations of both vegetarians as well as non-vegetarians, n=69 for jerky and n=56 for burger patty) was carried out using General Linear Model procedure of SAS Statistical Software. Student-Newman-Keuls test was used to test the significance of the difference at $p \leq 0.05$.

2.5. Objective Analysis

An Instron Universal Testing System (Model 1000, Instron Corp., Canton, MA) was used to measure shear force required to cut through the products. A 50 kg load cell and a Kramer Shear cell were used for the textural measurement. The jerky samples were cut into 3×0.6 cm, and the patty samples were cut into 3.5×1.5 cm strips. The samples were placed at right angles to the blade, and the crosshead speed was at 200 mm/min. The thickness of the samples were similar.

2.6. Results and Discussions

The sensory results of the jerky and burger patty products are shown in Tables 2.7 and 2.8. Pork jerky was superior to the prototype jerky and the commercial vegetarian jerky by over 1 mark in the appearance, texture and overall attributes. The appearance of

Table 2.7 – Sensory results of the jerky products

Characteristics	Pork Jerky	Prototype Jerky	Commercial Vegetarian Jerky
Appearance	6.6 [a]	5.5 [b]	5.5 [b]
Odor	6.3 [a]	6.3 [a]	4.7 [b]
Flavor	7.4 [a]	5.1 [b]	4.4 [b]
Texture	7.3 [a]	5.1 [b]	4.9 [b]
Overall	7.2 [a]	5.6 [b]	4.9 [c]

[a-c] Mean Values with the same superscript letters are not statistically different at $p \leq 0.05$.

Table 2.8 – Sensory results of the burger patties

Characteristics	Beef Burger Patty	Prototype Burger Patty	Commercial Vegetarian Burger Patty 1	Commercial Vegetarian Burger Patty 2
Appearance	5.7 [a]	4.8 [a]	5.5 [a]	5.6 [a]
Odor	6.6 [a]	5.6 [b]	5.1 [b]	5.7 [b]
Flavor	6.7 [a]	6.0 [b]	4.8 [c]	5.6 [b]
Texture	6.8 [a]	5.1 [b]	5.5 [b]	5.6 [b]
Overall	6.6 [a]	5.6 [b]	5.1 [b]	5.7 [b]

[a-c] Mean Values with the same subscript letters are not statistically different at $p \leq 0.05$.

the prototype jerky was very similar to that of the pork jerky, and was slightly superior to commercial vegetarian jerky. The odor of the prototype jerky was comparable to the meat jerky. The flavor and texture of the prototype jerky and commercial vegetarian jerky were very similar, but the overall score of the prototype jerky was higher though not significantly than that of commercial vegetarian jerky. The overall score of the prototype jerky was significantly higher than the commercial vegetarian jerky.

The appearance of the prototype burger patty was the lowest because of the greenish fiber present on the burger patty. The greenish color of the fiber may be reduced by soaking the fiber in soy sauce and the caramel color overnight before adding to tofu and spices. Ethanol may be used to leach chlorophyll from the fiber, but it would increase the production cost. The odor of the prototype burger patty was similar to commercial vegetarian burger patty 2 and was slightly better than commercial vegetarian burger patty 1. The flavor of the prototype burger patty was superior to commercial vegetarian burger patty 1, and slightly better than commercial vegetarian burger patty 2, but was lower than beef burger patty. The texture of the prototype burger patty was graded the lowest even though the Instron results were the closest to that of beef burger patty. Since, untrained panelists were used, their individual perception of the products had very strong influence on how they rated the samples. For example, even though the color of commercial vegetarian burger patty 2 was yellowish and its texture was soft, many of the panelists perceived it as a fish or chicken burger patty and thus graded its appearance and texture favorably. The flavor of commercial vegetarian burger patty 1 was graded very low probably because of the use of carrageenan in the product which gave it a distinct aftertaste. The odor of commercial vegetarian burger patty 2, though a little sour, was attractive to many panelists. The odor of the prototype burger patty was graded slightly lower than commercial vegetarian burger patty 2 but was better than commercial vegetarian burger patty 1. The texture rating of the prototype patty was low because of the high moisture content of the fiber which made it rather soft on chewing. The overall scores of the prototype burger patty was slightly lower than commercial vegetarian burger patty 2 but was higher than commercial vegetarian burger patty 1. The beef burger patty scored 1 point higher than the other products in all the attributes, except the appearance.

The flavor of prototype burger patty was found to affect the texture and the overall quality of the product. Thus, better flavor scores may increase the overall rating of the prototype products. Since the panelists were untrained, they seemed to have difficulties rating the texture and the overall quality independently of the flavor. Therefore, although results of the objective measurements showed that the prototype jerky and burger patty were very similar to their meat counterparts, their texture was rated low by the panelists. Thus, improving the flavor of the prototypes may improve their texture and overall scores. In addition, improvement of the appearance and reducing the moisture of the prototype burger patty may also improve the texture and overall scores of the product.

The frequency of the usage of tofu, jerky products, vegetarian products and meat products is summarized in Table 2.9. On average, most of the panelists did not consume tofu and jerky type products very often. Although the frequency of consuming vegetarian products was high, meat was the most frequently consumed products among the non-vegetarians. However, there were a few panelists who indicated that they prefer to consume vegetarian products than meat and only consume meat a few times a month. The frequency of using jerky type products was statistically related to the appearance, flavor and overall ratings of the prototype jerky. This may indicate that these attributes were very similar to meat jerky. However, the frequency of using tofu, vegetarian products and meat products had no relationship with the rating of the prototype burger patty. Incorporating rhubarb fiber in burger patty products seemed to be new to the panelists.

The panelists provided some useful comments. Many vegetarian panelists have never tasted meat jerky and do not consume fruit leather; therefore, they were not familiar with jerky products. However, they hope to find vegetarian jerky which is tasty and nutritious. On the other hand, even though non-vegetarians consume meat jerky, many of them complained that commercial meat jerky on the market have too much salt and are too tough to chew. Most of the panelists do not normally consume fruit leather because they are low in protein. From the comments, the market for the prototype jerky appears promising.

The results of objective texture measurement results are shown in Table 2.10. The shear-force curves are shown in Figures 2.10 and 2.11. The prototype jerky and burger

Table 2.9 – The frequency of using tofu, jerky products, vegetarian products and meat among the panelists

Category	Frequency of Usage
Tofu	0.5
Jerky Products	0.7
Vegetarian Products	1.4
Meat	2.0

0 = Never
1 = Light (1-4 times/month)
2 = Moderate (1 to 6 times/week)
3 = Heavy (1 or more times/day)

Table 2.10 – Instron measurements of the samples

Sample	Force (kg)
Prototype Jerky	26.8 ± 10.1
Pork Jerky	23.4 ± 4.5
Commercial Vegetarian Jerky	12.6 ± 4.5
Prototype Burger Patty	22.7 ± 3.1
Beef Burger Patty	28.4 ± 9.9
Commercial Vegetarian Burger Patty 1	17.2 ± 2.6
Commercial Vegetarian Burger Patty 2	9.7 ± 2.6

Figure 2.10 – Shear-force curve of the jerky samples

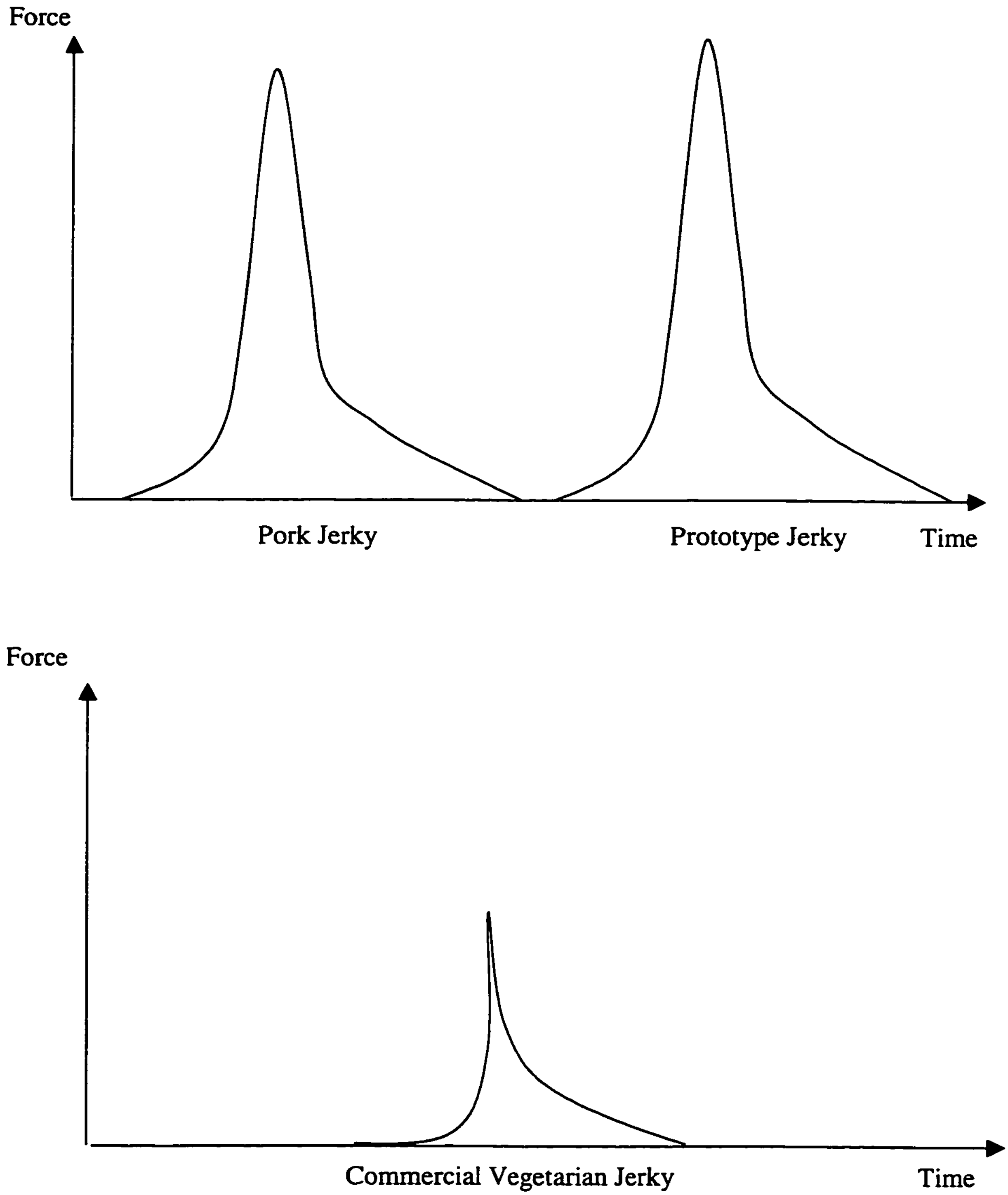
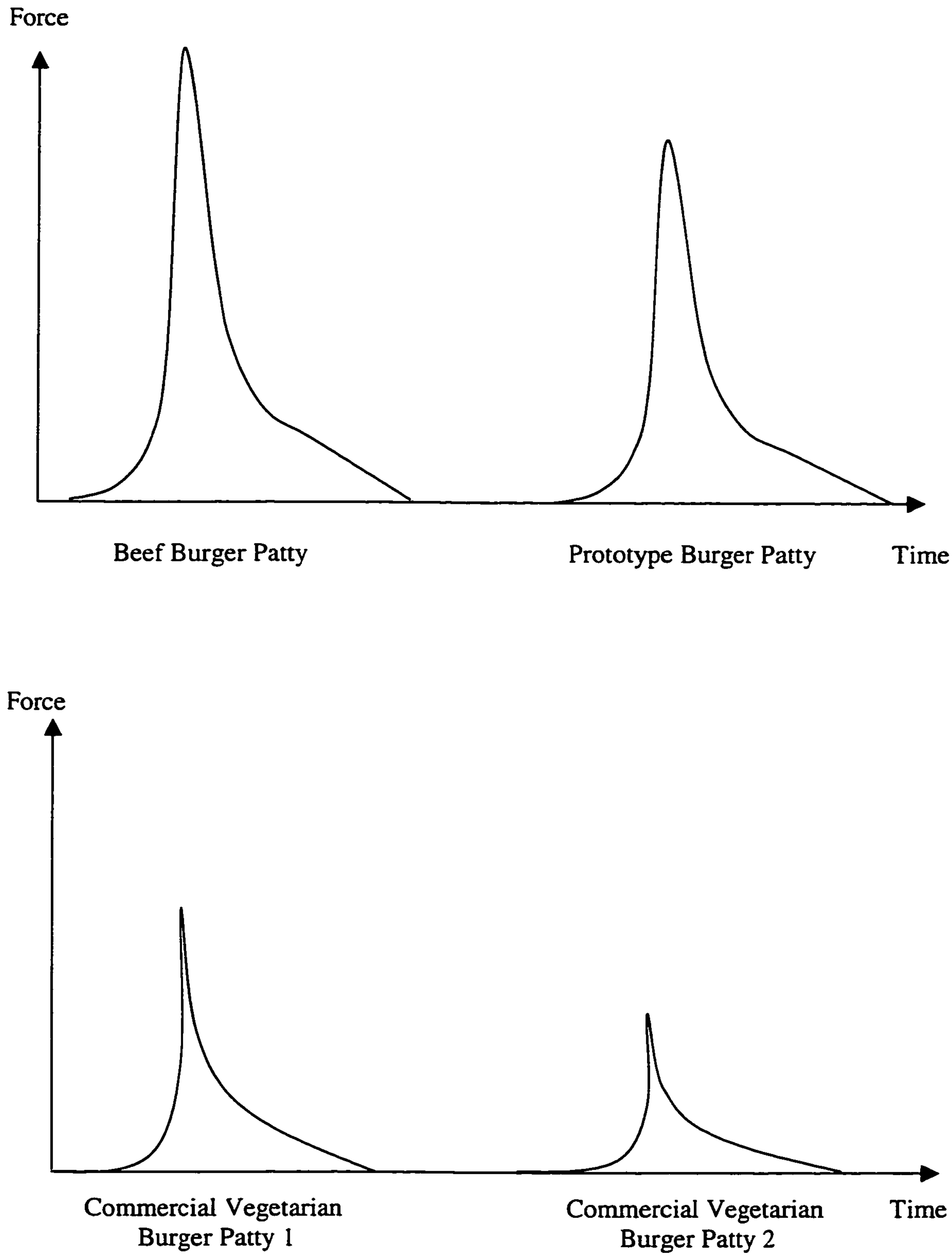


Figure 2.11 – Shear-force curve of the burger patty samples



patty had similar shear-force patterns to the meat products. The commercial vegetarian samples, however, was much lower in terms of shear-force, and they were soft as indicated by the sharp peak of the shear-force curves. Thus, the objective measurement shows that the addition of rhubarb fiber to the products was successful in increasing their chewiness, i.e. greater shear force is needed to cut through the fiber.

2.7. Conclusions

The prototype jerky was rated more favorable than the commercial vegetarian jerky by untrained panelists. To differentiate the acceptance of the product textures, the prototype jerky should be compared solely with the commercial vegetarian jerky. Better flavors are required to improve the rating of the prototype burger patty. In addition, the color of the fiber has to be modified to reduce the greenish color. The untrained consumers appeared unable to grade individual product attributes without being affected by other attributes. Even though texture measurements showed that the prototype products had similar shear-force patterns with the real meat products, the consumers graded the texture of the prototype burger patty low. Reducing the moisture of rhubarb fiber prior to incorporation into the product, and pressing the product with greater force may improve the texture and the overall scores of the prototype burger patty.

CHAPTER 3

PHYSICAL, CHEMICAL, MICROBIAL AND ECONOMIC PROPERTIES OF THE PROTOTYPE JERKY AND BURGER PATTY

3.1. Introduction

To evaluate other quality parameters of the products beside sensory quality, physical, chemical, microbial and economic analyses of the products were made. Some of these results are then related to the sensory results. For example, the color scores (L, a, and b values) of the samples were measured to determine the desirable color combination the consumers accepted the most. The water activity, moisture, and fat content partially indicated the mouthfeel of the samples when consumed, and pH indicated the sourness of the samples.

It was of interest to view the microscopic structure of the products using scanning electron microscopy to determine the interaction between the protein and rhubarb fiber, and possibly other ingredients. Rhubarb-coagulated tofu was also included as one of the samples. The images were compared with other studies conducted by Saio *et al.* (1979) and Atapattu (1993).

Calcium, protein, dietary fiber and lipid contents together with amino acid and fatty acid profiles were examined to evaluate the nutritional values of the prototypes. The calcium content of firm tofu was found to be 159 mg/100 g of tofu (Shurtleff and Aoyagi, 1979). At present, there is no vegetarian product with a calcium claim. Therefore, the concentration of calcium of the prototypes was measured. The protein, dietary fiber and lipid contents of the prototypes were compared with those of commercial products. Since soybean contains a high concentration of lysine but is low in cysteine and methionine, while wheat gluten is high in cysteine and methionine but low in lysine, the major essential amino acids of concern are lysine, cysteine and methionine These two protein sources are complementary to each other; thus, the prototypes should be sufficient in all the essential amino acids. The experimental results were compared to the amino acid profile of tofu and wheat gluten reported by Schroder and Jackson (1972) and Kasarda *et al.* (1976), respectively.

The oxalate content of the prototypes, which may be of concern for consumers, was measured to determine if the processing method was able to remove most of the oxalate from rhubarb fiber.

Numeration of microorganisms was conducted to establish the approximate shelf-life of the prototype jerky and uncooked prototype burger patty. The water activity of intermediate-moisture food is between 0.60 to 0.85 and the moisture content of intermediate-moisture food is around 15 to 50% (Jay, 1992). The water activity, moisture content and pH of the prototypes would also indicate the growth ability of some microorganisms. Suggestions were made to increase the stability of the prototypes. pH of the prototypes may be manipulated to reduce the rate of microbial growth.

The cost of the prototypes was estimated which would show the commercial potential of the prototypes and suggestions were made to reduce the production cost.

3.2. Materials and Methods

3.2.1. Physical Properties of the Products

3.2.1.1. Water Activity (a_w)

Samples were pureed and water activity was measured using AquaLab Water Activity Measurement Meter model CX-2 (Pullman, Washington) in 4 replicate.

3.2.1.2. Color

HunterLab Color Difference meter (model D25-2, Hunter Assoc. Laboratory, Fairfax, Virginia) was used in measuring the L, a and b values of the samples. The samples (in triplicate) were pureed and placed on petri dishes for the measurement.

3.2.1.3. Scanning Electron Microscopy (SEM)

Fresh samples were frozen and fractured in liquid nitrogen at –196°C. The samples were then put in the sample chamber filled with argon gas. The samples were heated gradually to –40°C to sublime all the ice crystals and then gold plated. The samples were examined using a JEOL X-Vision Scanning Microscope (Model JSM 6301 FXV, JEOL Ltd., Tokyo, Japan).

3.2.2. Chemical Properties of the Products

3.3.2.1. pH

pH of the pureed fresh samples (sample to water ratio of 1:3) was measured in 4 replicate using a Fisher Accumet selective analyzer (Model 750).

3.3.2.2. Moisture Content

Moisture of the samples was measured according to AOAC Method 950.46 (1995). Samples were measured in triplicate.

3.3.2.3. Ash Content

Ash content of the samples was determined in 4 replicate, according to AOAC Method 942.05 (1995).

3.3.2.4. Calcium Content

Samples were weighed (2 g of dried samples) and ashed at 525°C overnight, and 50 mL of 2.2 N nitric acid (with 5% lanthanum chloride) was added. A calcium reference standard (Catalog No. SC 191, Fisher Scientific, Nepean, On.) was diluted to 0.5 ppm, 1 ppm, 2 ppm, 3 ppm and 4 ppm, and the samples were diluted to be within the standards' range. The samples were then analyzed in 4 replicate using Perkin-Elmer 4000 Atomic Absorption Spectrophotometer (Perkin-Elmer Corp., Norwalk, CT) at 422.7 nm.

3.3.2.5. Oxalate Content

Double distilled deionized water (8 mL) and acetonitrile (20 mL) were added to 2 g of samples. The mixture was shaken and centrifuged for 5 min. The supernatant was decanted and 28 mL of 2N H_2SO_4 was added to the residue. The mixtures were shaken and centrifuged. The supernatant was filtered using Millipore Teflon membrane filter (Type HA 0.45µm, Millipore Corp. Bedford, MA) before injected into the HPLC. The HPLC system consisted of an Aminex HPX-87H Organic Acid Analysis Column (Bio-Rad Laboratories, Hercules, CA) and a UV 1305 Liquid Chromatography Detector (TSK-6040, Shimadzu Co., Japan). The wavelength used was 210 nm. The flow rate was at 0.7 mL/min and the temperature used was 65°C. The mobile phase was 0.009 N H_2SO_4. Standard curve of oxalate was prepared using 15.6 ppm, 31.25 ppm, 62.5 ppm, 125 ppm, 250 ppm, 500 ppm and 1000 ppm standards. The samples were diluted within the range of the standards. 4 replicate of the samples were analyzed.

3.3.2.6. Protein and Amino acid Content

The amounts of crude protein in the ingredients and the products were analyzed using AOAC Method 928.08 (1995). Amino acid composition was analyzed by digesting the samples using 6N HCl at 110°C overnight. The digested samples were analyzed by Varian 5000 HPLC (Varian Associates, Sunnyvale, CA) as described in Sedgwick *et al.* (1991). Triplicate of the samples was analyzed.

3.3.2.7. Total, Soluble, and Insoluble Dietary Fiber Content

The total, soluble and insoluble dietary fibers were analyzed in duplicate according to AOAC Method 991.43 (1995).

3.3.2.8. Lipid Content and Lipid Classes

Crude fat in the ingredients and the prototypes was analyzed according to the method described by Folch (1957). The extracted fat was methylated using a mixture of methanol (45%), BF_3 (35%), hexane (20%) at 95°C for 1 h. The methylated mixture was analyzed for the fatty acid classes by Varian 3600 Gas Chromatography (Varian Associates, Sunnyvale, CA), compared with a #411 GLC reference standard (Nu-Chek Prep. Inc., Elysian, MN). 4 replicate of the samples were measured.

3.2.3. Microbial Properties of the Products

AOAC Method 940.36A(g) (1995) was used to enumerate the total number of microorganisms in the samples on day 0 and 7. Petrifilm (3M Health Care, St. Paul, MN) were inoculated and were incubated at 22°C for 5 d to enumerate molds and yeasts in the products. 4 replicate of the samples were numerated.

3.2.4. Cost Estimation of the Products

The prices of the ingredients used in the estimation of product cost were obtained from food ingredient suppliers.

3.3. Results and Discussions

Water activity

Water activities of the samples are shown in Table 3.1. The a_w of intermediate-moisture foods is between 0.60 to 0.85 (Jay, 1992). At a_w near 0.86, *Staphylococcus aureus* may grow. The a_w of the prototype jerky was slightly higher than 0.85. This might provide a moist mouthfeel to the users. However, the growth of *S. aureus* may lead to foodborne diseases. Thus, it should be lowered by further drying or by adding ingredients (e.g. sorbitol) or by eliminating the application of corn syrup which might have reduced the drying rate. The a_w of the burger patty was similar to that of the other burger patty samples. Therefore, the products should have provided a moist mouthfeel to the users, but at such a high degree of water activity, microorganisms would grow rapidly. Thus, freezing of the prototype burger patty may be considered.

Color

Color scores of the samples are shown in Table 3.2. The color of the prototype jerky was similar to meat jerky. The appearance of the commercial vegetarian jerky was described as "plastic-like" by many of the participants. Compared to the prototype jerky, the pork jerky was darker and more reddish, but less yellowish. Commercial vegetarian burger patty 1 had a color more similar to the beef burger patty, but commercial vegetarian burger patty 2 was a yellowish products that many panelists described as

Table 3.1 – Water activity of the jerky and burger patty samples

Sample	Water Activity
Pork Jerky	0.749 ± 0.021
Prototype Jerky	0.870 ± 0.020
Commercial Vegetarian Jerky	0.848 ± 0.002
Beef Burger Patty	0.974 ± 0.012
Prototype Burger Patty	0.968 ± 0.010
Commercial Vegetarian Burger Patty 1	0.966 ± 0.002
Commercial Vegetarian Burger Patty 2	0.967 ± 0.010

Table 3.2 – Color scores of the jerky and burger patty samples

Sample	L	a	b
Prototype Jerky	29.3	10.6	11.4
Pork Jerky	25.8	17.1	8.8
Commercial Vegetarian Jerky	31.8	10.8	12.0
Prototype Burger Patty	28.3	5.7	10.5
Beef Burger Patty	36.5	4.7	11.3
Commercial Vegetarian Burger Patty 1	32.0	7.0	11.4
Commercial Vegetarian Burger Patty 2	51.2	8.6	20.9

chicken or fish burger. The color of the prototype jerky may be improved by adding more beet powder and caramel. On the other hand, the prototype burger patty and the commercial vegetarian burger patty 1 were too dark in color when compared with beef burger patty. The redness of the prototype burger patty was similar to that of the meat counterpart whereas commercial vegetarian burger patty 2 was too reddish when compared with beef burger patty. Commercial vegetarian burger 2 was designed completely differently than the traditional brown burger patty in terms of its color, flavor and texture. Instead of making it a traditional burger patty, it was designed to be a yellowish, fish or chicken burger-like product which was perceived as a soft burger patty. Its appearance, texture and the overall quality were rated high by the panelists who perceived it to be a better product.

In order to improve the appearance of the prototype burger patty, the greenish color of rhubarb fiber has to be minimized by leaching with ethanol, or simply by soaking the fiber in a coloring agent overnight as discussed previously. Since the latter method would not increase the processing cost, the method is recommended. In addition, less caramel color should be used in the prototype burger patty so that the product would be lighter in color. Since appearance affects other attributes, the improvement of the appearance will also improve the ratings of other attributes of the products.

Scanning Electron Microscopy

In Plate 1a, rhubarb fiber coils were shown. There were a few oxalate crystals contained in the cells surrounding the fiber coils. The crystals occupied about half of the cells. From the SEM micrographs, the helical fiber coils were of different sizes as shown in Plate 1b. These coils appeared to provide the space where tofu partially coagulated on the fiber bundles in rhubarb-coagulated curd. Attempts were made to use rhubarb juice to coagulate soy curd. However, the resulting curd was very soft and lack cohesiveness. This is because the curd consisted of loosely bonded protein globules as shown in Plate 2a. Plate 2b shows some rhubarb fiber coils filled with protein which had a well-ordered honeycomb structure which was likewise, reported by Atapattu (1993). Plates 3a, 3b, and 3c are micrographs of $CaSO_4$-coagulated tofu. The protein matrix is porous and there

Plate 1 – Scanning electron micrograph of processed rhubarb fiber

a – Calcium oxalate containing cells

b – Rhubarb fiber coils of different diameters

Plate 2 – Tofu coagulated with a mixture of rhubarb juice and fiber

a – Tofu coagulated with rhubarb juice and fiber

b – Soy protein coagulated inside fiber coils

<u>Plate 3 – Scanning electron micrograph of $CaSO_4$-coagulated tofu</u>

a, b, and c – $CaSO_4$-coagulated tofu at different magnifications seem to be numerous bonds linking the wall of the pores, making the protein matrix appear like honeycomb. Similar observation was made by Saio (1979).

In order to determine the interaction of ingredients, flavoring and coloring agents, wheat gluten and tofu were added to rhubarb fibers. When the flavoring and coloring agents were added to rhubarb fiber, some of the fiber coils were filled with the mixture as shown in Plate 4a, but the others were filled with cellular liquid. The magnified micrograph (Plate 4b) shows that the flavoring and coloring mixture as a piece of solid in which there are numerous spherical particles less than 1 micron in size. The spherical particles might be microorganisms that were present in soy sauce. Rolling and pressing of rhubarb fiber may have partially opened the fiber coils and, with subsequent rolling and pressing, the ingredients were able to enter the fiber coils.

Plates 5a, 5b, and 5c are micrographs of a mixture of rhubarb fiber and wheat gluten. From Plate 5a, it was shown that wheat gluten could not enter the fiber coils, which left the coils empty. That was because gluten formed very strong and cohesive matrix in the presence of water, thus it was difficult to press gluten into the coils. Outside of the coils, wheat gluten formed a very strong network with the fiber coils and other tissues (Plate 5b). A spherical starch granule was observed outside of the fiber coils which was approximately 5 micron in diameter (Plates 5b and 5c).

When tofu was mixed with rhubarb fiber, the fiber coils were filled as shown in Plate 6a. The tofu outside of the fiber coils (Plate 6b) was similar to $CaSO_4$-coagulated tofu (Plates 3a, 3b and 3c) but appeared different from the protein structure within the fiber coils. It appeared that tofu entered rhubarb fiber coils quite readily after mixing. That was because coagulated soy curd was more loosely formed than gluten matrix and could be more easily squeezed into the coils. In addition, it might be possible that some of the uncoagulated soy protein formed curd inside fiber coils with organic acid that might be present in the coils, thus appeared to have different structure from the protein on the outside.

For the prototype jerky, the substances inside the fiber coils (Plates 7a and 7vb) was well compressed and was similar to the protein mixture outside of the fiber coils (Plate 7c) and was also similar to $CaSO_4$-coagulated tofu (Plates 3a, 3b, and 3c). The protein matrix was tightly compressed during the production of the prototype jerky. The

Plate 4 – Scanning electron micrograph of rhubarb fiber in flavoring and coloring agents

a – Rhubarb fiber coils surrounded by flavoring and coloring agents

b – Close-up of a mixture of flavoring and coloring agents surrounding the fiber coils

Plate 5 – Scanning electron micrograph of wheat gluten and rhubarb fiber

a – Empty fiber coils

b and c – Gluten matrix at high magnification showing starch granules

Plate 6 – Scanning electron micrograph of tofu and rhubarb fiber

a – Tofu inside fiber coils

b – Tofu outside of the fiber coils

Plate 7 – Scanning electron micrograph of prototype jerky

a and b – Filled fiber coils at different magnification

c – A mixture of tofu, wheat gluten and flavoring and coloring agents outside the fiber coils mixture inside the fiber coils of prototype jerky was very likely a mixture of tofu and flavoring and coloring agents. As discussed previously, it would be difficult for wheat gluten to be forced into the fiber coils, but this may be more clearly illustrated with other types of microscopy, such as environmental microscopy, which is not available in the university at present. The protein mixture formed strong bonds with the rhubarb fiber coils and other rhubarb tissues, which contributed to the firmness and chewiness of the prototype jerky.

Since there was a high concentration of wheat gluten in the burger patty formulation as compared to the jerky, a large number of starch granules (approximately 5 micron in diameter) in wheat gluten were observed (Plates 8a and 8b). With higher concentration of wheat gluten, a more cohesive gluten matrix was formed, making it more difficult for tofu to separate from the mixture and be squeezed into the fiber coils. Hence, the patty appeared to have less protein in the fiber coils (Plates 8c and 8d).

pH

pH of the samples are shown in Table 3.3. pH of the prototype jerky and burger patty were similar but slightly lower than the commercial vegetarian products because of the remaining acid in the rhubarb fiber and the acid in smoke flavor. The acidity of the prototype jerky may be increased if a smoke house was used during the process rather than adding smoke flavor into the product. According to the panelists, the slight sourness did not affect the taste of the products. If pH of the prototype burger patty was adjusted to less than 4.5 by the addition of ingredients such as tomato paste and pickles, vacuum packaging may be used to package the prototype burger patty, since at such low pH, *Clostridium botulinum* cannot grow or produce toxins.

Moisture

The moisture content of the samples is shown in Table 3.4. According to Shurtleff and Aoyagi (1979), the typical moisture content of firm tofu is 79.3%. The moisture content of the tofu used in the production of the prototypes was much lower, which indicates that the tofu used was an extra firm tofu.

The moisture content of intermediate-moisture food is around 15 to 50% (Jay, 1992). The moisture content of the jerky was within the range. Conventional beef burger

Plate 8 – Scanning electron micrograph of prototype burger patty

a and b – A mixture of tofu, wheat gluten and flavoring and coloring agents outside the fiber coils

c and d – Partially filled fiber coils

Table 3.3 – pH of the jerky and burger patty samples

Sample	pH
Prototype Jerky	5.566 ± 0.094
Meat Jerky	6.403 ± 0.073
Commercial Vegetarian Jerky	5.530 ± 0.022
Prototype Burger Patty	5.126 ± 0.010
Beef Burger Patty	6.120 ± 0.049
Commercial Vegetarian Burger Patty 1	6.121 ± 0.089
Commercial Vegetarian Burger Patty 2	6.160 ± 0.032

Table 3.4 – The moisture content of tofu, and the jerky and burger patty samples

Sample	Moisture Content, %
Tofu	72.98 ± 0.32
Prototype Jerky	33.14 ± 1.95
Meat Jerky	32.99 ± 0.19
Commercial Vegetarian Jerky	28.46 ± 0.04
Prototype Burger Patty	62.41 ± 0.19
Beef Burger Patty	51.27 ± 0.13
Commercial Vegetarian Burger Patty 1	72.97 ± 0.31
Commercial Vegetarian Burger Patty 2	57.45 ± 0.48

contains 55.0% moisture (Jay, 1992). The prototype burger patty contained much higher moisture than beef burger patty and commercial burger patty 2, but less than commercial burger patty 1. It is possible to produce prototype burger patty with lower moisture content if a more suitable press was used to remove moisture from rhubarb fiber. This would produce a firmer burger patty, which appeared to be what the panelists preferred.

Ash

The ash content of tofu, processed rhubarb fiber, prototype jerky and burger patty is shown in Figure 3.1. The ash content of the prototype jerky was much higher than that of the prototype burger patty and tofu because most of the moisture was taken out from the jerky during the drying process. Thus, the jerky had a higher solid content than other samples. It is expected that most of the ash consisted of calcium since tofu was coagulated with $CaSO_4$, and calcium in rhubarb fiber existed essentially as calcium oxalate.

Calcium Content

Calcium content of tofu and the processed rhubarb fiber, prototype jerky and burger patty is shown in Figure 3.2. The calcium content of the processed rhubarb fiber was relatively low when compared with that of tofu. Similar to the ash content, the calcium content of the prototype jerky was higher than that of tofu because solid content was increased during the drying process. Up to date, there has been no claim of high calcium on vegetarian products. Since the prototype jerky contains more than 25% (RDI=1100 mg) of the recommended daily intake (RDI) of calcium per normal serving of 60 g, the products may be labeled as "excellent source of calcium". The prototype burger patty may be labeled as good source of calcium (10 to 19% of RDI). No commercial products claim to have high calcium content, thus giving the prototypes an added nutritional advantage.

Oxalate Content

The oxalate content of fresh rhubarb fiber, processed rhubarb fiber and the prototype jerky and burger patty is shown in Figure 3.3. The total oxalate content in the processed rhubarb fiber was about 6% of that in the fresh rhubarb fiber. Therefore, the

Figure 3.1 – Ash content of tofu, processed rhubarb fiber and prototype jerky and burger patty

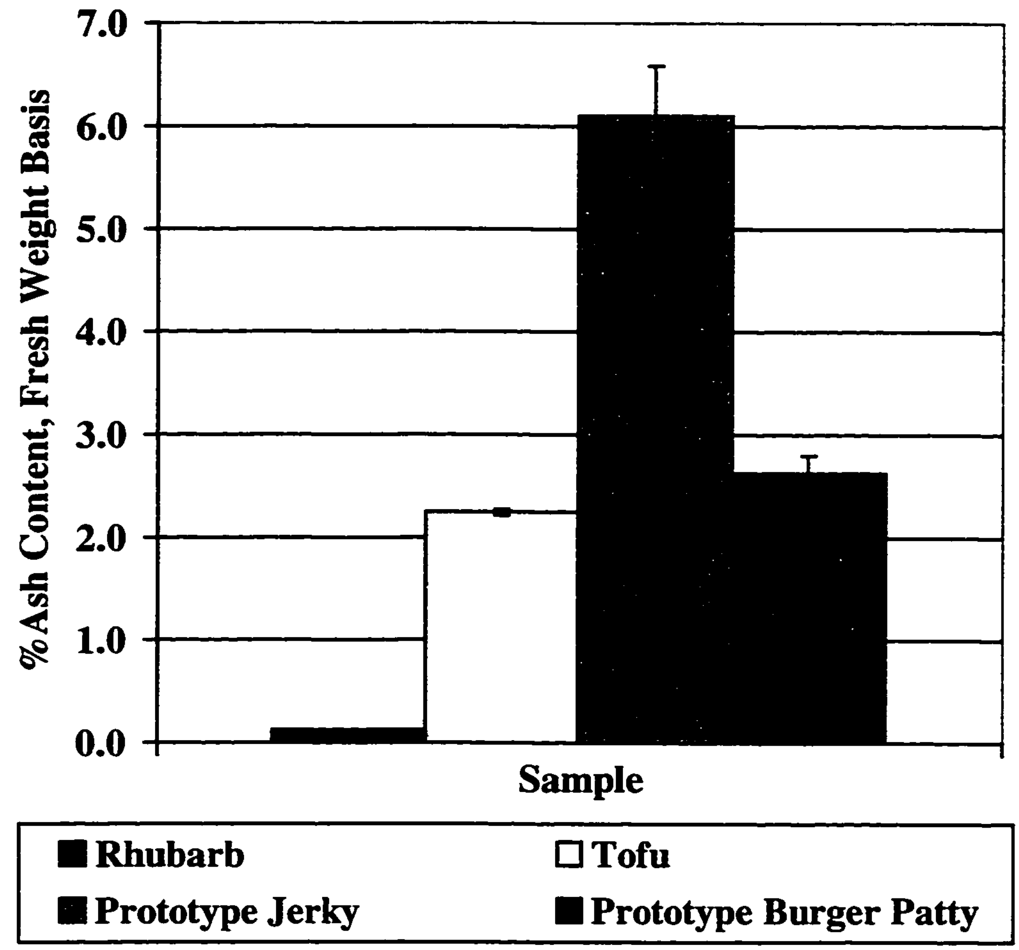


Figure 3.2 – Calcium content of tofu, processed rhubarb fiber and prototype jerky and burger patty

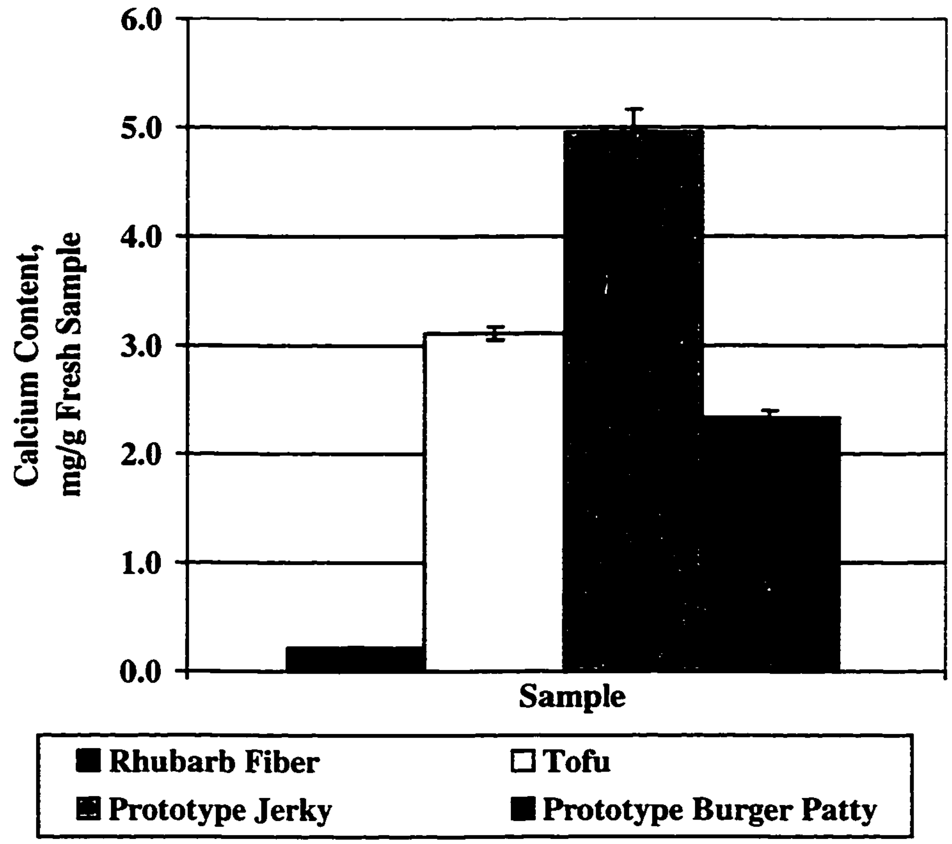
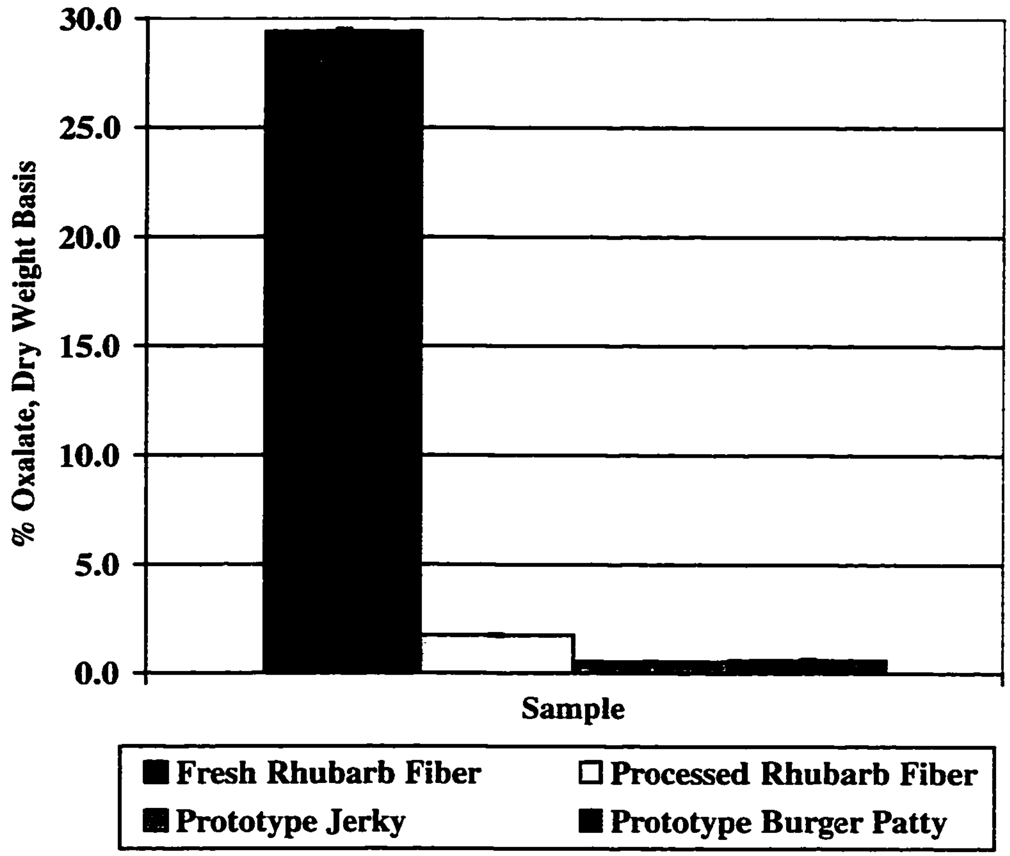


Figure 3.3 – Oxalate content of fresh and processed rhubarb fiber, and prototype jerky and burger patty



fiber processing method was successful in reducing the oxalate content in fresh rhubarb fiber. Although it is safe to consume rhubarb stalks, some of the consumers may negatively consider the effect of long term consumption of rhubarb on their calcium absorption, as cautioned by some researchers. Since the process reduced the oxalate content significantly, the chance of calcium oxalate stone formation is reduced. Moreover, some researchers suggested that the formation of kidney stones was due to the increasing consumption of animal protein (Robertson *et al.*, 1979a; Robertson *et al.*, 1979b; Breslau *et al.*, 1988; Kok and Papapoulos, 1993).

Protein Content and Amino Acid Composition

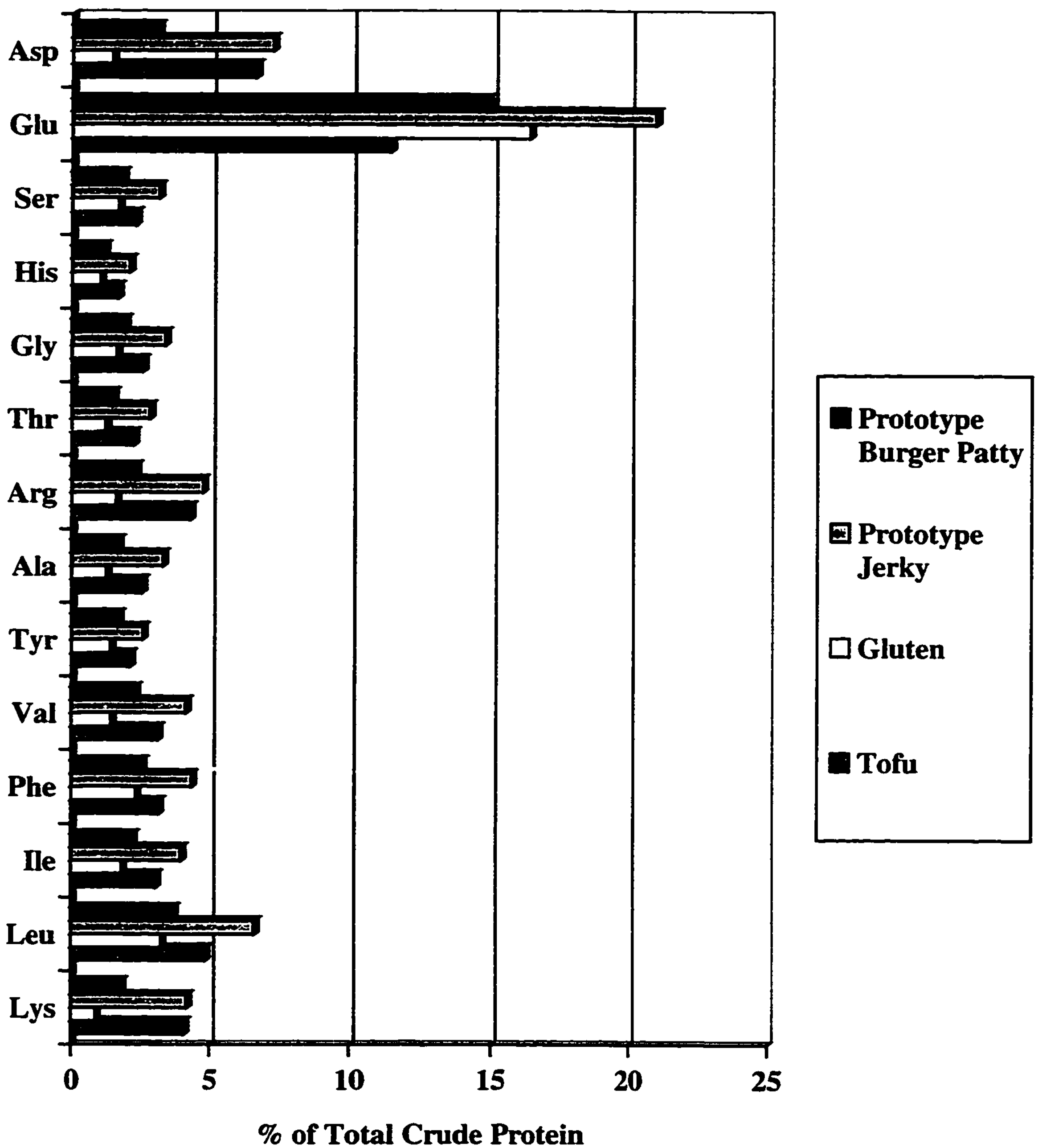
The protein content of tofu, wheat gluten and the prototype jerky and burger patty is shown in Table 3.5. Protein content of the prototypes was very high because of the added wheat gluten. For the prototype jerky, 58% of the protein was provided by tofu and 42% from wheat gluten. On the other hand, the major source of protein in the prototype burger patty was wheat gluten (68%) and tofu contributed 32%. The commercial vegetarian jerky has a protein content of about 17% and fruit leather only have about 1.3% protein. The prototype jerky had a much higher protein content, with more acceptable taste; thus, it can be a more nutritious and popular snack than other non-meat jerky products. Commercial vegetarian burger patties have approximately 13% protein content, which was much lower than that of the prototype burger patty. Other binding agents such as Redisol 4 or pregelatinized taro starch may be used to replace part of the wheat gluten to reduce the cost. The suggested protein content would be above 16% for burger patty, which is comparable to other processed meat products. Since wheat gluten was used, which formed very strong gluten network in the presence of water, the products became quite cohesive. For the prototype jerky, the solid content slowly increased during the relatively low temperature drying and the product formed even stronger internal bonds. Together with the structural support of rhubarb fiber, the finished product was firm, chewy but quite flexible.

The amino acid profile of tofu, wheat gluten, prototype jerky and burger patty is shown in Figure 3.4. The major essential amino acids of concern are lysine, cysteine and

Table 3.5 – The protein content of tofu, wheat gluten, and prototype jerky and burger patty

Sample	% Protein, Dry Weight Basis	% Protein, Fresh Weight Basis
Tofu	49.90 ± 3.31	13.47 ± 0.89
Wheat Gluten	75.64 ± 0.71	72.46 ± 0.68
Prototype Jerky	36.83 ± 0.02	24.53 ± 0.38
Prototype Burger Patty	58.91 ± 7.96	22.15 ± 2.99

Figure 3.4 – Amino acid profile of tofu, wheat gluten, and prototype jerky and burger patty



methionine. Soybean contains high concentration of lysine but is low in cysteine and methionine, while wheat gluten is high in cysteine and methionine but low in lysine. From the experimental results, it was shown that tofu contained three times more lysine than gluten. The amino acid composition of wheat gluten was similar to that reported by Kasarda *et al.* (1976) and that of tofu was similar to the values reported by Schroder and Jackson (1972). The lysine concentration of 60 g of prototype jerky and 90 g of burger patty was over 1 g. The requirement of lysine is 16 mg/g protein (Waggle, *et al.*, 1989). Thus, the prototypes can provide sufficient lysine to the consumers.

Fiber Content

The percent total, soluble and insoluble dietary fiber of the dried samples are summarized in Table 3.6. It was shown that the flavoring samples which contained high concentrations of spices were high in insoluble fiber. Since, spices were not the major ingredients, they contributed only a small amount of dietary fiber. Tofu contained some dietary fiber, probably because a small portion of the pureed soybean fiber passed through the cheesecloth layers into the soymilk. The major source of dietary fiber was rhubarb fiber. Rhubarb fiber, which was surrounded and bonded by the protein matrix, provided a strong structural support. This is similar to the concept of buildings in which steel bars (rhubarb fiber) provided structural support to concrete (protein matrix). When compared with commercial products which do not contain long fiber strands, the prototypes could withstand higher shear forces as shown by the results of texture measurements. Nutritionally, rhubarb fiber not only provided roughage but also soluble dietary fiber which can be digested by microflora. As shown by Goel *et al.* (1997), rhubarb fiber can lower total cholesterol, low-density lipoprotein (LDL), and triglycerides in human subjects. Moreover, a high fiber diet may reduce the risk of some types of cancer. When the prototype jerky is compared with the commercial vegetarian jerky (0% fiber content), its fiber content was much higher. Meat jerky products do not contain any dietary fiber; thus, the prototype jerky has an advantage over the meat counterpart in this respect.

Table 3.6 – Total, soluble, and insoluble dietary fiber content of rhubarb fiber, tofu, jerky and burger patty flavorings, and the prototype jerky and burger patty

Sample	% Total Dietary Fiber, Dry Weight Basis	% Soluble Dietary Fiber, Dry Weight Basis	% Insoluble Dietary Fiber, Dry Weight Basis
Rhubarb Fiber	77.8	15.0	62.9
Tofu	5.4	1.3	4.1
Jerky Flavoring	14.4	4.7	9.7
Burger Patty Flavoring	52.2	23.0	29.3
Prototype Jerky	12.0	0.6	11.5
Prototype Burger Patty	12.2	1.8	10.5

Lipid Content and Fatty Acid Profile

The crude lipid content of tofu and the prototype jerky and burger patty is shown in Table 3.7. The fatty acid profile of tofu and the prototype jerky and burger patty is shown in Figure 3.5. The lipid content of the samples was relatively high because whole soybeans were used. To lower the amount of lipid in the products, defatted soybean flour may be used in tofu making. The fatty acid profile of the samples and that of soybean oil reported by Sonntag (1979) are shown in Figure 3.5. The saturated, monounsaturated and polyunsaturated fatty acid composition of tofu and the prototypes was similar to that reported by Pringle (1974). Since tofu was the major source of lipid, the fatty acid profile of the prototypes was very close to that of tofu as well as that reported by Sonntag (1979). To increase the ω-3 to ω-6 polyunsaturated fatty acid ratio, other oilseeds such as flaxseed may be included in the formulation. For the prototype jerky, its lipid content (10.23%) was lower than that of the commercial vegetarian jerky (20%). For the prototype burger patty, the amount of its crude fat (5.63%) was lower than commercial vegetarian burger patty 2 (10%) but higher than commercial vegetarian burger patty 1 (<1%). Although high concentrations of lipid provide better mouthfeel, the amount of lipid should be lowered in the prototypes for nutritional reason. Since the prototypes contain polyunsaturated fatty acids, antioxidants may have to be added to prevent rancidity of the products during storage.

Microbial Properties

The number of bacteria, yeasts and molds of soy sauce, tofu, processed rhubarb fiber as well as the fresh and 7 days old prototype jerky and burger patty are shown in Table 3.8. The number of bacteria in tofu was within the safety limit suggested by Rehberger *et al.* (1984). The major sources of bacteria, yeasts and molds were from the rhubarb fiber and tofu. Even though the fiber was steamed, the heating process was insufficient to destroy all the microorganisms in the stalks. Likewise, with tofu prepared from soybean. The drying process in the jerky production could not kill all the microorganisms in the jerky. After one week of storage, the number of bacteria remained about the same, but yeasts and molds grew in number. Thus, anaerobic packaging may be

Table 3.7– Crude lipid content in tofu, prototype jerky and burger patty

Sample	% Crude Lipid Content, Fresh Weight Basis
Tofu	8.59 ± 0.29
Prototype Jerky	10.23 ± 0.40
Prototype Burger Patty	5.63 ± 0.48

Figure 3.5 – Fatty acid profile of tofu, and prototype jerky and burger patty as compared to literature values for soybean oil (Sonntag, 1979)

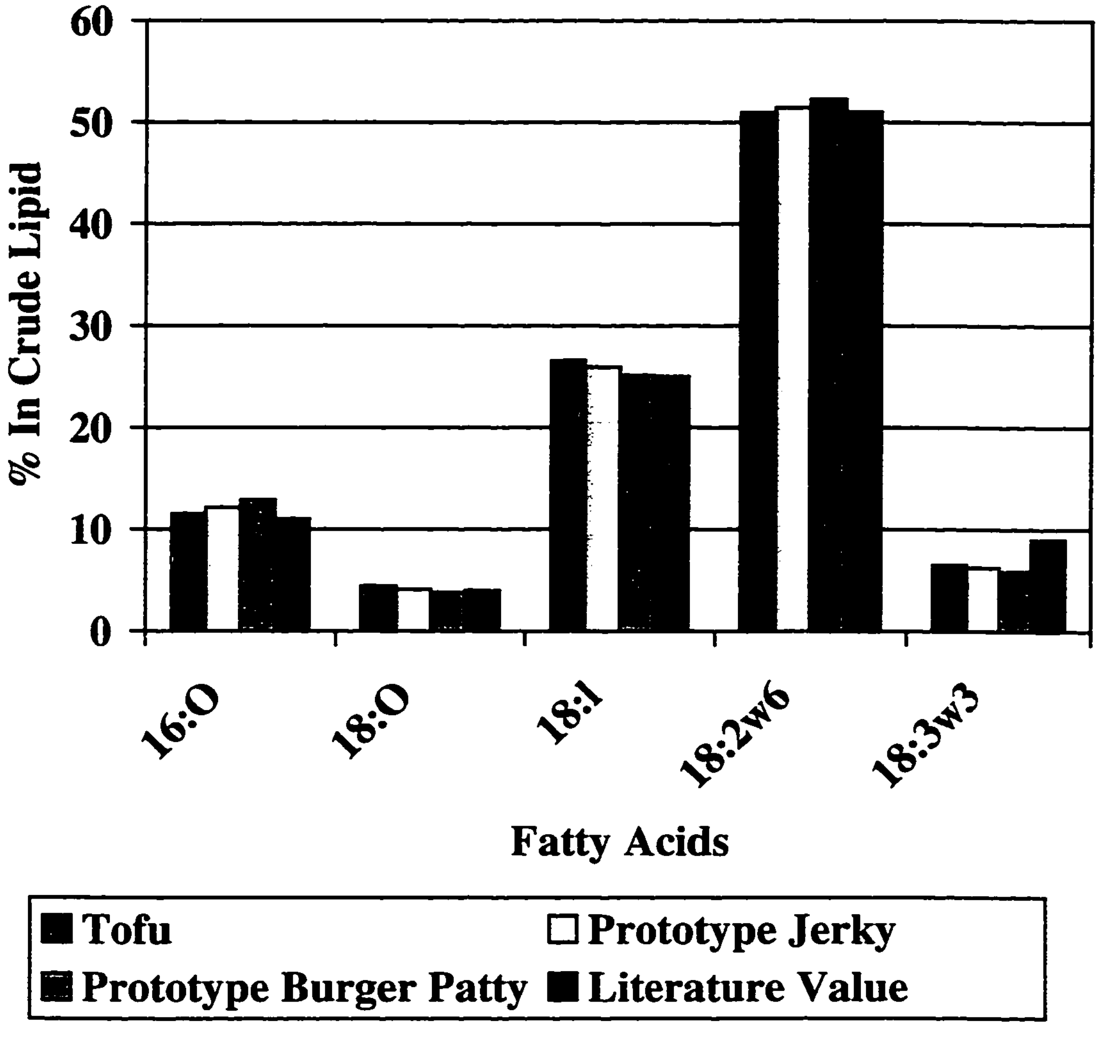


Table 3.8 – Number of bacteria and yeasts and molds in soy sauce, tofu, processed rhubarb fiber and the fresh and 7 days old prototype jerky and burger patty

Sample	Bacteria/g Sample	Yeasts and Molds/g Sample
Soy Sauce	2.0×10^2	2.0×10^2
Tofu	8.8×10^4	5.8×10^3
Rhubarb Fiber	1.3×10^5	1.8×10^3
Prototype Jerky	1.2×10^5	6.0×10^3
7 d Old Prototype Jerky	1.5×10^5	2.3×10^5
Prototype Burger Patty	2.5×10^5	5.5×10^3
7 d Old Prototype Burger Patty	2.0×10^5	4.2×10^4

considered. For the burger patty, the number of microorganisms grew slightly during the storage period. Freezing storage may be considered to increase the storage life. Application of preservatives may also be considered, but health-concerned consumers may not accept the practice. The prototype jerky needed further drying and the syrup coating may be eliminated to aid the drying process. As discussed previously, pH of the burger patty may be lowered so that vacuum packaging may be used to slow down the rate of microbial growth.

Cost of Materials

The cost of ingredients and the estimated material cost of the prototype jerky and burger patty are shown in Table 3.9 and the approximate retail price is shown in Table 3.10. The suggested amount of product for a package of the prototype jerky and burger patty is 60 g and 180 g, respectively. The production costs of one package of prototype jerky and burger patty are $ 1.04 and $ 2.72, respectively. The price of the jerky product can be lower than meat jerky products produced in Canada. However, the prototype jerky is more expensive than the imported products which are made with low grade, fatty meat. The ingredient cost of the burger patty is relatively high, but it may be lowered by partially substituting one of the major ingredients such as wheat gluten with Redisol 4 or pregelatinized taro starch.

3.5. Conclusions

The color of the prototype jerky may be modified to make it more comparable to meat jerky. This can be achieved by adding more beet powder and caramel color. The flavor may be improved by smoking the product in a smoke house instead of using smoke flavor, which makes the jerky sour and the flavor was too light. The texture of the prototype jerky can be harder if the jerky was dried for a longer period of time or by eliminating the syrup coating which slowed down the rate of drying.

The color of the prototype burger patty may be improved by increasing the amount of caramel, and by reducing the greenish color of the fiber. The fiber used should also be pressed with stronger pressure to remove more moisture. The patty requires a proper mold press to squeeze the ingredients more tightly together. An addition of tomato

Table 3.9 – Cost of ingredients for 1000 kg of prototype jerky and burger patty

Ingredient	Prototype Jerky	Prototype Burger Patty
Tofu Ying Fat Tofu Factory, Edmonton, AB.	$ 421	$ 263
Wheat Gluten Canasoy (Canada) Co. Ltd., Vancouver, B.C.	$ 444	$ 799
Flavoring and Coloring Agents UFL Foods Ltd. Edmonton, AB.	$ 661	$ 329
Rhubarb Stalk	$ 270	$ 180
Total	**$ 1796**	**$1571**

Table 3.10 – Estimated retail price of prototype jerky and burger patty

Cost/Price Estimate	180 g Burger Patty	60 g Jerky
Average Consumer Price	**$5.75**	**$2.20**
Less 30% Retail Margin	$1.73	$0.66
Wholesale	$4.02	$1.54
Less 25% Wholesale Margin	$1.01	$0.39
Processor's Price	$3.01	$1.16
Less 10% Company's Profit	$0.30	$0.12
Production Cost	$2.71	$1.04

paste and pickle to the burger patty may be considered, which would potentially reduce the cost of packaging and storage while improving the flavor at the same time.

SEM micrographs show that the mixture of soy curd and wheat gluten formed bonds with rhubarb fiber. With higher concentration of wheat gluten, less protein can be squeezed into fiber coils because of the cohesiveness of the gluten network.

Rhubarb fiber provided structural support to the products. The protein matrix interacted with rhubarb fiber and formed bonds; therefore, the prototype jerky was flexible, hard and chewy, and the prototype burger patty was also chewier than the commercial vegetarian patties. The prototype products are good sources of calcium, protein, and fiber and can provide sufficient lysine to the consumers. The prototypes have low oxalate content, which shows that the processing method was sufficient in reducing the oxalate content from rhubarb fiber. Although the lipid content was lower than some of the commercial products, it was still relatively high. The lipid content may be lowered by using defatted soybean flour to make tofu. The lipid profile may be altered by including other oilseeds such as flaxseed, to increase the ω-3 to ω-6 fatty acid ratio. The cost of the ingredients may be lowered by substituting part of the wheat gluten with taro starch and Redisol 4 pregelatinized starch in the burger patty.

CHAPTER 4
GENERAL CONCLUSIONS AND RECOMMENDATIONS

Vegetarian "meat-like" food products, such as jerky and burger patty, with improved texture, may be produced from a mixture of soybean curd, rhubarb fiber, binding, coloring and flavoring agents. Vegetarian jerky has been made by mixing tofu, wheat gluten, rhubarb fiber strands, coloring and flavoring agents, formed and pressed into thin sheet and partially dried. Vegetarian burger patty has been made from similar ingredients, but with higher quantity of gluten, molded and pressed into a cohesive product.

Sensory evaluation showed that in comparison with commercial products, the prototype jerky was more acceptable to the panelists than the commercial products. The color of the prototype jerky was similar to the commercial meat jerky, but it may be modified by adding more beet powder and caramel color. The flavor of the jerky may be improved with a smoke flavor by using a smoke house instead of adding smoke flavor. Further drying will be necessary to reduce a_w, which will reduce microbial growth.

The prototype burger patty was not rated significantly different from commercial vegetarian burger patties. This was partly because of the low appearance rating due to the greenish color of rhubarb fiber in the product. The texture, though chewy, was considered too soft because of the high moisture content of rhubarb fiber. Nevertheless, texture measurement of the prototype patty showed similar shear force was required to cut through the product as that needed for beef burger patty. This indicates that rhubarb fiber does, indeed, impart chewiness to the product. To improve the quality of the prototype patty, the greenish color of rhubarb has to be removed or reduced. A better press is needed to more efficiently remove water from the fiber, and to form a more cohesive and firmer burger patty product. The color of the burger patty may be improved by reducing the amount of caramel color. Rhubarb fiber may be soaked in flavoring and coloring agents before incorporating into the patty so as to reduce the greenish color of the fiber. Red rhubarb species may also be used instead of the green ones. pH of the prototype patty may be reduced further to make the product more stable so that refrigeration and vacuum packaging can be used instead of freezing.

SEM micrographs show that protein in the mixture bonded with rhubarb fiber both inside and outside the fiber coils. This contributed to the flexibility, firmness and chewiness of the products, especially the prototype jerky. A high wheat gluten concentration in the mixture appeared to limit the amount of protein pressed into the coils. This was shown by the fact that in the prototype jerky, in which less gluten was used, more protein was present in the fiber coils than in the prototype patty, in which more gluten was added.

The prototypes were nutritionally superior to the commercial vegetarian products. The prototypes are good sources of dietary fiber which can lower the total cholesterol, low-density lipoprotein, and triglycerides levels. Rhubarb fiber incorporated into the prototypes also provided structural support to the products. The prototypes contained high concentrations of calcium. The amount of oxalate in the products was significantly reduced during rhubarb fiber processing, and thus, reduce the possible risk of calcium oxalate stone formation. The prototype products are high in protein which consists of all the essential amino acids from both legumes and cereals. The prototypes had generally less fat than commercial products. Although the lipid content in the products was relatively high, it may be lowered by using defatted soybean flour to make tofu. The lipid profile may be altered by including other oilseeds such as flaxseed to the products to increase the ω-3 to ω-6 fatty acid ratio. The cost of the ingredients may be lowered by substituting part of the wheat gluten with taro starch and Redisol 4 pregelatinized starch in the burger patty. The retail price of the prototype jerky should be lower than some meat jerky products.

Although the rhubarb-coagulated soy curd could not be used for the production of prototype jerky and burger patty, the method may be used to produce a non-dairy "yogurt" for consumers who are allergic to milk proteins. The processing method developed for the prototype jerky and burger patty may be used to make different types of vegetarian products of different textures, e.g. vegetarian pepperoni, fish finger, sausages, and steak by changing the ratio of tofu to rhubarb fiber and other ingredients.

To minimize oil absorption during cooking, a layer of food gum coating may be used on the prototype burger patty. The products may also be fortified with other vitamins and minerals such as iron, etc., to make them more nutritious. Nutrition yeast may also be added to provide vitamin B_{12}, which is usually insufficient in vegan's diets.

With the apparent high demand for vegetarian food products, the prototypes should have a promising market. Convenient, nutritious and palatable products which contain high protein, high fiber, and other desirable nutrients can become popular food items in the "food-on-the-go" market.

REFERENCES

Abdulla, M., Andersson, I., Asp, N.G., Berthelsen, K., Birkhed, D., Dencker, I., Johansson, C.G., Jagerstad, M., Kolar, K., Nair, B., Nilsson-Ehle, p., Norden, A., Rassner, S., Akesson, B., and Ockerman, P.A. 1981. Nutrient intake and health status of vegans. Chemical analyses of diets using the duplicate portion sampling technique. Am J. Clin.Nutr. 34(11): 2464-2477.

Adlercreutz, H., Mousavi, Y., Clark, J., Hockerstedt, K., Hamalainen, E., Wahala, K., Makela, T., and Hase, T. 1992. Dietary phytoestrogens and cancer: *In vitro* and *in vivo* studies. J Steroid Biochem. Molec. Biol. 41: 331-337.

Anonymous, 1996. Vegetarians usually lean. Med. Post Oct 15, 1996, 32(35): 21.

AOAC. 1995. *Official Methods of Analysis,* 16th ed. Association of Official Analytical Chemists, Washington, DC.

Atapattu, C. 1993. Texture improvement of meat-based food analogs with rhubarb fiber. MSc Thesis, University of Alberta, AB.

Barnard, N.D., Nicholson, A., and Howard, J.L. 1995. The medical costs attributable to meat consumption. Preventive med. 24: 646-655.

Basu, T.K., Ooraikul, B., and Garg, M. 1993. The lipid lowering effects of rhubarb stalk fiber: a new source of fiber. Nutr. Res. 13: 1017-1024.

Beccari. 1745. *De Bononiensi Scientiarum et Artium Instituto Atque Academia*. 2: 122-127. Cited in Knight, J.W. (1965), *The Chemistry of Wheat Starch and Gluten and Their Conversion Products*, p. 84. Leonard Hill, London.

Beilin, L., Rouse, I.L., Armstrong, B.K., Oxon, D.P., Margetts, B.M., and Vandongen, R.

1988. Vegetarian diet and blood pressure levels: incidental or causal association? Am. J. Clin. Nutr., 48: 806-810.

Boyers, R.A. 1954. High protein food product and process for its preparation. US Patent 2682466.

Breidenstein, B.C. 1988. Changes in consumer attitudes toward red meat and their effect on marketing strategy. Food Technol. 42: 112-116.

Breslau, N.A., Brinkley, L, Hill, K.D., and Pak, C.Y.C. 1988. Relationship of animal protein-rich diet to kidney stone formation and calcium metabolism. J. Clin. Endo. Met. 66(1): 140-146.

Bumgamer, M.A., 1976. *The Book of Whole Grains*. P. 281-286. St. Martin's Press, New York, NY.

Cai, J.W. 1997. Utilization of rhubarb in manufacturing of quarq products and investigation of their nutritional value. MSc thesis. University of Alberta, Edmonton, AB.

Chang-Claude, J., Frentzel-Beyme, R., and Eilber, U. 1992. Mortality pattern of German vegetarians after 11 years of follow-up. Epidemiology 3(9): 395-401.

Chen, S. 1989. Principles of soymilk production. Ch. 3, In *Food Uses of Whole Oil and Protein Seeds,* Lusas, E.W., Erickson, D.R., and Nip, W.K. (Ed.), 40-86. American Oil Chemists' Society, Champaign, IL.

Conze, E. 1975. *Further Buddhist Studies*. Bruno Caeeirer (Publishers) Ltd., London.

Cross, H.R. and Byers, F.M. (Ed). 1990. *Current Issues in Food Production: A Perspective on Beef As A Component in Diets for Americans: A Scientific*

Response to John Robbin's "Diet for a New America". College Station, TX: Texas A & M University, Department of Animal Science.

Dai, Y. and Luo, X. 1996. Functional food in China. Nutr. Rev. 54(11): S21-S23.

Dwyer, J.T. 1988. Health aspects of vegetarian diets. Am. J. Clin. Nutr. 48: 712-738.

Dwyer, J.T., Goldin, B.R., Saul, N., Gualtieri, L., Barakat, S., Adlercreutz, H. 1994. Tofu and soy drinks contain phytoestrogens. J. Am. Diet. Asso. 94(7): 739-743.

Ewart, J.A.D. 1977. Re-examination of the Linear Glutenin Hypothesis. J. Sci. Food Agric. 28:191-199.

Folch, J.P., Lees, M., and Stanley, G.H. 1959. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226: 497-509.

Food Marketing Institute, 1996. [In Food Technol. 51(3): 55-58.]

Food Safety and Inspection Services, U.S. Department of Agriculture. 1993. Pathogen reduction: hazard analysis critical control point (HACCP) systems. Fed. Reg. 60(23): 6781-2.

Giddey, C. 1983. Phenomena involved in the "texturization" of vegetable proteins and various technological processes used. Qual. Plant Plant Foods Hum. Nutr. 32:425-437.

Giese, J. and Katz, F. 1997. Ethical marketing of functional foods. Food Technol. 51(12): 58-61.

Goel, V., Ooraikul, B., and Basu, T. 1996. Effect of dietary rhubarb stalk fiber on the bioavailability of calcium in rats. Int. J. Food Sci. and Nut. 47:159-163.

Goel, V., Ooraikul, B., and Basu, T. 1997. Cholesterol lowering effects of rhubarb stalk fiber in hypercholesterolemic men. J. Am. Coll. Nutr. 16(6): 600-603.

Goh, J.K. 1996. Personal communication. Tai Chung Tofu Factory, Taiwan.

Gregerson, J. 1992. Vegetarianism- A history, Jain Publishing Company, Fremont, CA.

Harper, J.M. 1981. *Extrusion of Foods*. Vol. I. CRC Press, Inc., Boca Raton, FL.

Hasler, C.M. 1996. Functional Foods: The western perspective. Nutr. Rev. 54(11): S6-S10.

Hauser, S. 1991. The rhubarb stalker. National Gardening (1/2): 50-53.

Hollingsworth, P. 1997. Mainstreaming Healthy Foods. Food Technol. 51(3): 55-58.

Huffman, D.L. and Cordray, J.C. 1985. Formulations for restructured red meat products. Ch. 11, In *Advances in Meat Research*, Pearson, A.M. and Dutson, T.R. (Ed.), 383-404. Van Nostrand Reinhold Co. Inc., New York, NY.

Jay, J.M. 1992. *Modern Food Microbiology*, 4th ed. Chapman & Hall, New York, NY.

Kasarda, D.D., Bernardin, J.E., and Nimmo, C.C. 1976. Wheat proteins. Adv. Cereal Sci. Technol. 1:58.

Khan, K. and Bushuk, W. 1979. Structure of wheat gluten in relation to functionality in breadmaking. Ch. 10. In *Functionality and Protein Structure*. Gould, R.F. (Ed.), p.191-206. American Chemical Society, ACS Symposium Series.

Kohyama, K. and Nishinari, K. 1993. Rheological studies on the gelation process of soybean 7S and 11S proteins in the presence of glucono-delta-lactone. J. Agric. Food Chem. 41: 8-14.

Kok, D.J. and Papapoulos, S.E. 1993. Physicochemical considerations in the development and prevention of calcium oxalate urolithiasis. Bone and Min. 20: 1-15.

Koshiyama, I., Hamano, M., Fukushima, D. 1981. A heat denaturation study of the 11 S globulin in soybean seeds. Food Chem. 6: 309-322.

Lamey, M. 1996. Fat free fast food. Vancouver Sun, August 12, 1996.

Lappe, F.M. 1975. *Diet for a Small Planet*, Ballantine Books, Inc. New York, NY.

Matsudomi, N., Mori, H., Kato, A., Kobayashi, K. 1985. Emulsifying and foaming properties of heat-denatured soybean 11S globulins in relation to their surface hydrophobicity. Agric. Biol. Chem. 49:915-919.

Menzi, R. and Rufer, W. 1981. US Patent 477513. Battelle Memorial Institute, Carouge, Switzerland.

Messina, M. and Messina, V. 1997. Soy: Good food for good health. Veggie Life (May, 1997), 48-50, 55.

Messina, M.J., Persky, V., Setchell, D.R., and Barnes, S. 1994. Soy intake and cancer risk: a review of the *in vitro* and *in vivo* data. Nut. and Cancer 21(2): 113-131.

Olsen, M.E. 1972. *History of the Origin and Progess of Seventh-Day Adventists.* AMS Press, Peekshill, NY.

Ooraikul, B., Atapattu, C., Basu, T., Smit, M.E. and Liang, B.M. 1993. Development of dietary fibre and other value-added products from rhubarb stalks. Final report to Alberta Agricultural Research Institute, Edmonton, AB.

Ornish, D., Brown, S.E., Scherwitz, L.W., Billings, J.H., Armstrong, W.T., Ports, T.A., McLanahan, S.M., Kirkeeide, R.L., Brand, R.J., and Gould, K.L. 1990. Can lifestyle changes reverse coronary heart disease? Lancet 336:129-133.

Phillips, R.L. and Snowdon, D.A. 1983. Association of meat and coffee use with cancers of the large bowel, breast, prostate among Seventh-Day Adventists: Preliminary results. Cancer Res. 45: 2403s-2408s.

Prevention Index, The. Emmaus, Pa. 1996. [In Food Technol. 51(7): 24.]

Pringle, W. 1974. Full-fat soy flour. J. Am. Oil Chem. Soc. 51:74A-76A.

Proctor, V.A. and Cunningham, F.E., 1986. Egg Jerky-A research Note. Poultry Sci 65(3): 592-593.

Realeat Survey Office, The. The *Realeat Survey* 1984-1993, 1995. Changing Attitude to Meat Consumption. Altrincham: The Realeat Company Ltd. The Vegetarian Society.

Rehberger, T.G., Wilson, L.A., and Glatz, B.A. 1984. Microbiological quality of commercial tofu. J. Food Protect. 47(3): 177-181.

Richardson, B.J. 1994. UK Consumer perceptions of meat. Proc. of the Nutr. Society 53: 281-287.

Richardson, B.J., Shepherd, R., and Elliman, N. 1994. Meat consumption, definition of meat and trust information sources in the UK population and members of the vegetarian society. Ecology of Food and Nut. 33:1-13.

Robb, H.F. 1919. Death from rhubarb leaves due to oxalic acid poisoning. J. Am. Med. Assoc., 73: 627-628.

Robbins, J. 1987. *Diet for a New America*. Stillpoint Publishing, Walpole, NH.

Robertson, W.G., Peacock, M., Heyburn, P.J., Hanes, F.A., Rutherford, A., Clementson, E., Swaminathan, R., and Clark, P.B. 1979a. Should recurrent calcium oxalate stone formers become vegetarians? Br. J. of Urol. 51: 427-431.

Robertson, W.G., Peacock, M., and Hodgkinson, A. 1979b. Dietary changes and the incidence of urinary calculi in the U.K. between 1958 and 1976. J. Chron. Dis. 32: 469-476.

Saio, K. 1979. Tofu- relationships between texture and fine structure. Cereal Foods World 24(8): 342-354.

Schroder, D.J. and Jackson, H. 1972. Preparation and evaluation of soybean curd with reduced beany flavor. J. Food Sci. 37: 450-451.

Schultz, J. 1996. World's most popular style of eating is catching on in Canada. Edmonton Journal, Oct 30, 1996, E1, Edmonton, AB.

Sedgwick, G.W., Fenton, T.W., and Thompson, J.R. 1991. Effect of protein precipitating agents on the recovery of plasma free amino acids. Can J. Anim. Sci. 71: 953-957.

Shurtleff, W. and Aoyagi, A. 1979. *The Book of Tofu*, vol. I. 12th ed. Ballantine Books, Westminister, MD.

Sims, L.S. 1978. Food-Related value-orientations, attitudes, and beliefs of vegetarians and non-vegetarians. Ecol. Food. Nut. 7:23-35.

Singtao Electronic News, 1998a. Hong Kong News (Chinese). http://www.singtao.com. Jan 16, 1998.

Singtao Electronic News, 1998b. Hong Kong News (Chinese). http://www.singtao.com. Jan 20, 1998.

Sloan, E. 1997a. The not-so-healthy market. Food Technol. 51(6): 32.

Sloan, E. 1997b. The C-store: A sleeping giant. Food Technol. 51(10): 28.

Sloan, E. 1998. Moving to minerals. Food Technol. 52(3): 18.

Snyder, H.E. and Kwon, T.W. 1987. *Soybean Utilization*. Van Nostrand, New York, NY.

Sonntag, N.O.V. 1979. Composition and characteristics of individual fats and oils. Ch. 6. In Bailey's *Industrial Oil and Fat Products*, Vol. I, 4^{th} ed. Swern, D. (ed.). John Wiley & Sons, Inc., New York, NY.

Stackhouse, J. 1996. Maharaja Mac set to invade India. Globe and Mail, Oct 12, 96, A1, A15.

Stoneman, D. 1993. Market study says price isn't key. Farm and Country 57(18): 37.

Tajiri, T. 1993. Physical properties of tofu produced using citrus fresh fruit juice and ume-zu as coagulation agent- Studies on the process of produced and quality of tofu part 1. Nippon Shokuhin Kogyo Gakkaishi 40(11): 814-823.

Teenage Research Unlimited, 1991. [Montreal Gazette, Oct 6, 1996. D10.]

Teenage Research Unlimited, 1996. [Montreal Gazette, Oct 6, 1996. D10.]

Toronto Vegetarian Association. 1997. Personal Communication.

Tsai, S.J., Lan, C.Y., Kao, C.S. and Chen, S.C. 1981. Studies on the yield and quality characteristics of tofu. J. Food Sci. 46: 1734-1737, 1740.

Vegetarian Resource Group. 1997. Personal Communication.

Waggle, D.H., Steinke, F.H., and Shen J.L. 1989. Isolated soy protein. Ch. 4, In *Legumes: Chemistry, Technology, and Human Nutrition*, Mattews, R.H. (ed.), 99-138. Marcel Dekker, Inc., New York.

Wang, H.L. and Hesseltine, C.W. 1982. Coagulation conditions in tofu processing. Process Biochem. 17: 7.

Wilkens, W.F., Mattick, L.R., and Hand, D.B. 1967. Effect of processing method on oxidative off-flavors of soybean milk. J. Food Sci. 27: 262-265.

Wrick, K.L. 1993. Functional foods: cereal products at the food-drug interface. Cereal Foods World 38(4): 205-214.

Yorks, T.P. 1978. Energy use in soybean meat analog manufacture: a comparison with beef. J. Sci. Food. Agric. 29:895-902.

Ziemba, J. 1969. Simulated Meats-How they're made. Food Eng 41(11): 72-75.

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6″

APPLIED IMAGE, Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989