QUALITY CHARACTERISTICS AND UTILIZATION OF POTATO FLOUR

Thesis

Submitted to the

G. B. Pant University of Agriculture & Technology

PANTNAGAR-263145, (U. P.) INDIA

By

Anupama Misra

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Doctor of Philosophy

(Human Nutrition)

JUNE, 2000

ACKNOWLEDGEMENT

With profound sense of gratitude, I express my deepest regard and reverence to the Chairperson of my Advisory Committee, Dr.(Mrs.) Kalpana Kulshreshtha, Associate Professor, Department of Foods & Nutrition, G.B.P.U.A.&T., Pantnagar. I am thankful to her for the constant guidance, encouragement and assistance rendered to me throughout the period of investigation.

My sincere thanks are also due to Mrs.L.Bhattacharya, Associate Professor; Dr.(Mrs.) S. Srivastava, Associate Professor, Department of Foods & Nutrition, Dr.N.P.Singh, Associate Professor, Department of Vegetable Science and Dr.G.S.Chauhan, Professor and Head, Department of Food Science and Technology, members of my Advisory Committee for providing all assistance and guidance in conducting the research work.

Thanks are also due to Head, Department of Foods & Nutrition; Dean, College of Home Science and Dean, College of Post Graduate Studies for providing the necessary facilities for carrying out the research work. Facilities provided by the University Library and the Home Science Library during the entire course of degree programme are duly acknowledged.

I am especially thankful to my friends Shubhanjana, Seema, Lolita and S. K. Upadhyay for their inspiration, moral boosting and cooperation during the period of my stay at the campus.

My heartfelt emotions are due to all family members for their unending love, affection, encouragement, inspiration, constant help and their moral support throughout my study period, without their blessings and best wishes, this difficult task was impossible to be completed.

The financial assistance in the form of fellowship received during the course of research work is duly acknowledged. Thanks are due to Dr.P.G.Biswas and Mr.Prabhakar Joshi for providing efficient computer facilities.

Pantnagar

June, 2000

Anupama Misra

(Anupama Misra)

Authoress

Dr.(Mrs.) Kalpana Kulshreshtha
Associate Professor

Department of Foods and Nutrition
College of Home Science
G.B.Pant University of Agriculture &
Technology, Pantnagar-263 145
Distt. U.S.Nagar (U.P.), India

CERTIFICATE

This is to certify that the thesis entitled **"QUALITY CHARACTERISTICS AND UTILIZATION OF POTATO FLOUR"** submitted in partial fulfilment of the requirements for the degree of **Doctor of Philosophy** with major in **Human Nutrition** of the College of Post-Graduate Studies, G. B. Pant University of Agriculture & Technology, Pantnagar, is a record of *bona fide* research carried out by **Ms. ANUPAMA MISRA**, Id.No.**18048**, under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been acknowledged.

16.6.2000

(KALPANA KULSHRESHTHA)
Chairperson
Advisory Committee

CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Ms. ANUPAMA MISRA**, Id.No. **18048**, a candidate for the degree of **Doctor of Philosophy** with major in **Human Nutrition** agree that the thesis entitled **"QUALITY CHARACTERISTICS AND UTILIZATION OF POTATO FLOUR"** may be submitted in partial fulfilment of the requirements for the degree.

(KALPANA KULSHRESHTHA)
Chairperson

(LEENA BHATTACHARYA)
Member

(G.S.CHAUHAN)
Member

(SARITA SRIVASTAVA)
Member

(N.P.SINGH)
Member

Adg. **Head**
(Department of Foods & Nutrition)
Ex-Officio member

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Introduction

INTRODUCTION

Potato (*Solanum tuberosum*) is a crop of considerable importance in the world food production **(Rao, 1998)** and is nowadays the most important and extensively grown horticultural crop in India **(Sikka, 1996)**. Potatoes are one of the most commonly consumed food items because of their high production, relatively low cost of production, adaptability to a wide variety of soil and climate types and easy-to-cook methods **(Chalom *et al.*, 1995; Shirsat and Thomas, 1998)**. Potato is a versatile food, which can be prepared in a great variety of dishes. It can be eaten as a staple food, as a complementary vegetable, as a snack item or processed into several forms, and in any of these roles, it enhances the nutritional quality of the diets of people **(Chadha, 1994)**.

Potato occupies fourth place among the food crops in the world after wheat, rice and maize in total production. Among the root crops, it tops the list and has the distinction of occupying the largest area under any single vegetable in the world **(Grewal, 1993; Rao, 1998; Ezekiel *et al*, 1999)**.

Potato is grown in about 140 countries, which are over 70 per cent of the countries in the world. India has the distinction of ranking fourth in production as well as area earmarked for cultivation in the world, after China, Poland and USA. In India, potatoes are grown in almost all the states and under adverse agro-climates, thereby producing potatoes in the country all the year round in one part or the other. The Indo-Gangetic region-Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal and the union territory of Delhi are the potato bowl of the country, besides north, north western, north eastern hills and in plains in different seasons **(Chadha, 1994).**

Potato is a widely adaptable crop and gives high production per unit area and time and can substantially supplement food needs of our country. Potato yield in terms of calories and proteins per hectare is considerably higher than that of the leading foodgrains such as wheat and rice **(Kaldy, 1972; Sangwan, 1991).** Potato has also excelled the cereal crops such as rice and wheat by registering higher growth rates during the last four decades **(Shekhawat and Ezekiel, 1999).** The 5.96 per cent annual increase in potato production can be compared to 5.50 per cent for wheat, 2.77 per cent for rice and 2.72 per cent for total foodgrains during 1949-50 to 1997-98 **(Shekhawat, 1999).** Despite a dismal foodgrain production of 193.12 million tonnes in 1997-98, the production of prominent tuber crop, potato, was all time high and was 62.30 lakh tonnes more than the production of the year, 1996-97 **(Indian Farmers' Digest, 1999).** By 1996-97, the area for potato cultivation increased to 1.49 million hectares and the production to 28.70 million tonnes with an average yield of 19.2 tonnes/hectare **(Shekhawat and Ezekiel, 1999).**

Potatoes are versatile as well as unique in the sense that they can fit into any meal and are good for breakfast, lunch or dinner. They can be used in almost every type of vegetable to make them palatable. Potatoes mixed with cereals and legumes produce acceptable food products. Moreover, potatoes can be consumed in various forms as boiled, fried, baked, roasted, steamed and even in several processed forms such as french fries, chips, papad, flakes, dice, cubes, granules, flour, canned potatoes etc.

Potatoes contribute significantly to the nutritive value of a meal. Infact, potato is not an especially a rich source of energy, but contain good quality edible grade protein, dietary fiber, several minerals and trace elements, essential vitamins and little or negligible fat **(Chalom *et al.*, 1995; Shekhawat and Ezekiel, 1999)**. The potato tubers are considered a well-balanced food with regard to ratio of protein to calories. Besides this, potato is considered a wholesome, nutritious and low energy food as compared to other cereals and staples and roots and tubers **(Horton and Sawyer, 1985)**. Even cooked potatoes have a lower calorific value than cooked cereals and pulses **(Chadha, 1994)**.

Although, potato is one of the chief vegetables and a staple diet for a large part of the world, the principal disadvantage associated with the crop is that it is seasonal and the bulk of the crop produced has a shorter storage life **(CIP, 1984)**. Moreover, with the increasing potato production every year in the country and the inadequacies of the proper storage infrastructure and transportation facilities, there occur localized seasonal gluts which cause occasional slumps in the prices during harvest period, and hence a loss to the producers.

Inadequate storage facilities of potato tubers also result in a greater proportion of wastage as the time advances. Moreover, as the existing cold storage capacity is not enough and also not within the reach of common man, it is important to find out some useful methods to prevent wastage and utilize the surplus potatoes **(Sagar and Roy, 1997; Gahlawat and Sehgal, 1998)**. Under such circumstances, the post harvest processing of the bulky, perishable, fresh tubers into dehydrated potato products would benefit both producers and consumers, as it helps to extend the storage life and serve as a means to increase the supply in off-seasons.

The processing of potatoes extend the shelf life and involve low cost of production, which may solve the problem of storage as well as availability of potatoes in different forms, all the year round, in a price effective manner. Moreover, the change from fresh to processed form is due to increased demand for convenience foods and fast foods.

Most of the potato processing is presently confined to the developed countries and it is only in the initial stage in India. However, fast growth in potato processing is expected to occur in India due to increased urbanization, preference of new generation for easy-to prepare and fast foods, increasing per capita income, increase in number of working women and expanding tourist trade **(Marwaha and Sandhu, 1999).**

Hence, in order to make the processed/dehydrated potato products available throughout the year, it would be desirable to develop appropriate technology for the production of dehydrated products such as dehydrated chips, dices, granules, flakes and flour **(Marwaha, 1997).** Among such dehydrated products, potato flour is the oldest, commercial processed potato product. Potato flour is a powder like product, prepared from potatoes and is used for various purposes.

Regarding the diversified uses of potato flour, it is widely used by the baking industry in preparation of bread and biscuits. It is also used as a combined thickening-flavouring agent in products such as dehydrated soups, gravies and sauces etc. Potato flour can also be used for preparing snack items such as tikkis and papad etc and in the preparation of idli and alu bhujia etc.

During the season, when potatoes are cheap, potato flour can be prepared and stored in the airtight containers and incorporated into various recipes. Processing of potatoes into flour is perhaps the most satisfactory method of creating a product that is not only nutritionally adequate but also remain for an extended period without damage and requires less rigorous storage control than the raw tubers and the processed products require less storage space **(Hadziyev and Steele, 1979)**.

Thus, keeping in view the increase in production and inadequacy of proper storage infrastructure, simple processing technology to convert bulky, perishable fresh potatoes into dehydrated products will be helpful to gain the maximum benefit from the crop both economically as well as in the utilization of the crop in developing some food products.

Therefore, considering the above, the present investigation was undertaken with the following objectives:

1. To study the physico-chemical characteristics of potato flour prepared from different potato varieties.
2. To study the nutritional value of potato flour prepared from different potato varieties.
3. To study the microbial load of potato flour samples of all the varieties.
4. To study the effect of storage on the physico-chemical characteristics, nutritional value and microbial load of potato flour from all the varieties stored at different durations and conditions.
5. Formulation of food products using potato flour and to study the sensory and nutritional characteristics of such products.

Review of Literature

2. REVIEW OF LITERATURE

Potato (*Solanum tuberosum* L.) is one of the important crops, capable of nourishing the great populations of the world **(Talburt and Smith, 1987)**. Potato is the most popular and largely consumed convenient major food item throughout the world because of its high yield, high production, high calorific value, relatively low cost of production, adaptability to a wide variety of soil and climate types and above all, its easy-to-cook methods **(Shirsat and Thomas, 1998)**.

With the increasing production of potatoes every year, there occur occasional slumps in the prices due to temporary gluts often caused during harvest period. Therefore, processing of potatoes has become an imperative necessity to avoid gluts and the consequent difficulty of storing large quantities of potatoes during periods of extremely high temperature. Processing is, nowadays, a fast growing sector within the world potato economy and the demand for processed potato products is increasing with increased utilization and the preference for ready recipes in the modern age **(Marwaha, 1997)**.

Dehydration is one of the major means of preserving potatoes, giving products such as potato flour, granules, flakes, chips, dice and also extraction of starch. Among the several processed products from potatoes such as dehydrated products, french fries, puffed products and canned products, potato flour is an important oldest commercial product, which can give remunerative return to the farmers and can be used for various food purposes by the consumers during off-season, when cost of potatoes is very high **(Sagar and Roy, 1997; Marwaha, 1997)**.

Hence, in order to make processed potatoes products available throughout the year to common population, it would be desirable to develop an appropriate technology for the development of dehydrated products such as potato flakes, granules, dice and flour. Among such dehydrated products, potato flour is the oldest, commercial processed potato product. It is a powder like product, prepared from potatoes, used in several food preparations. During the season when potatoes are cheap, potato flour can be prepared and stored in the air tight containers and incorporated into recipes **(Marwaha, 1997)**. It is in this context, the present study was undertaken and pertinent literature review is presented under the following heads and sub-heads:

2.1 Importance of potato as a food crop

2.2 Area and production

2.3 Nutritional value and biochemical composition of potatoes

2.3.1 Dry matter

2.3.2 Carbohydrates

2.3.3 Total starch

2.3.4 Moisture

2.3.5 Nitrogenous constituents/protein

2.1 Importance of potato as a food crop

Potato is a starchy tuber crop with a bland taste and this quality of potato makes its use easier in various food preparations. In India, potato is used as an important vegetable and any vegetable without potato is thought to be incomplete. Besides this, potatoes find a significant place in various snack preparations which are both palatable and hunger satisfying. Moreover, they can be stored easily for a long period of time without refrigeration as compared to other vegetables **(Talburt and Smith, 1987)**.

Potatoes, apart from maize are grown in more number of countries than other crops. It is a major non-cereal food crop ranking fourth after wheat, rice and maize in total production **(Lal, 1980; CIP, 1984; Horton and Sawyer, 1985; Sikka, 1996)**. According to a joint study conducted recently by the FAO and CIP in 1995, the crop is consumed by over one billion people worldwide and is a part of the diet of half a billion consumers in developing countries **(Sikka, 1996)**.

Potato is a dietary stable in most of the developed countries, while consumed as a vegetable in developing countries **(CIP, 1984; Horton and Sawyer, 1985; Sangwan, 1991)**. Potatoes are mostly consumed fresh in preparation of curries etc. and some portion is dehydrated or canned. In addition to this, potatoes are processed at home in different forms like chips, papad, flakes, french fries, flour etc. and as other snack items **(Amla and Shankar, 1975)**. Potatoes are also considered suitable for salads, mashed potato and french fry manufacture, but are not used as a part of regular diet **(Reust *et al.*, 1993)**. Potato is a versatile food which can be prepared in a great variety of dishes and has its own distinctive texture and flavour. It can be eaten as a staple food, as a complementary vegetable or as a snack food and in any of these roles, it enhances the nutritional quality of the diets of children or adults **(Chadha, 1994)**.

for a long period of time without refrigeration as compared to other vegetables **(Talburt and Smith, 1987)**.

Potatoes, apart from maize are grown in more number of countries than other crops. It is a major non-cereal food crop ranking fourth after wheat, rice and maize in total production **(Lal, 1980; CIP, 1984; Horton and Sawyer, 1985; Sikka, 1996)**. According to a joint study conducted recently by the FAO and CIP in 1995, the crop is consumed by over one billion people worldwide and is a part of the diet of half a billion consumers in developing countries **(Sikka, 1996)**.

Potato is a dietary stable in most of the developed countries, while consumed as a vegetable in developing countries **(CIP, 1984; Horton and Sawyer, 1985; Sangwan, 1991)**. Potatoes are mostly consumed fresh in preparation of curries etc. and some portion is dehydrated or canned. In addition to this, potatoes are processed at home in different forms like chips, papad, flakes, french fries, flour etc. and as other snack items **(Amla and Shankar, 1975)**. Potatoes are also considered suitable for salads, mashed potato and french fry manufacture, but are not used as a part of regular diet **(Reust *et al.*, 1993)**. Potato is a versatile food which can be prepared in a great variety of dishes and has its own distinctive texture and flavour. It can be eaten as a staple food, as a complementary vegetable or as a snack food and in any of these roles, it enhances the nutritional quality of the diets of children or adults **(Chadha, 1994)**.

In the total energy provided for the human nutrition, potato ranks fifth among the world food crops **(Sharon, 1985)**. It provides relatively more quantity of carbohydrates and calories per unit of edible weight than most of the vegetables. It also produces more of major food ingredients per unit of area in much shorter period and potato yield in terms of calories and protein per hectare, is considerably higher than that of the leading foodgrains such as wheat and rice **(Kaldy, 1972; Sangwan, 1991)**. Potatoes produce 74.5 per cent more food energy and 54 per cent more protein per unit area than wheat and 58 per cent more energy and 77.6 per cent more protein than rice **(Thorton and Sieczka, 1980)**.

The National Commission on Agriculture emphasized the need to increase both its consumption and production as the crop is considered to be complementary for meeting the deficit in cereals production, especially in the years of adverse weather conditions **(Sangwan, 1991)**.

Potato produces more food per unit area and time. Potato is a versatile food which enhances the nutritional quality of the diets of children or adults, hence people should be encouraged to develop a taste towards this commodity and give potatoes a rightful place in our diet **(Nagaich, 1977; Chadha, 1994)**. Moreover, potatoes can be consumed instead of cereals, and it is therefore, required that the National Nutrition Board, National Institute of Nutrition and other agencies involved in potato promotion, should standardize new dishes of potato which can be eaten as the main food and organize special meals to popularize these dishes. Besides, potatoes should be given as kind wages under the Jawahar Rojgar Yojna, and other employment guarantee schemes implemented by the government, which would ensure higher per capita consumption and certainly be instrumental in absorbing increased production **(Shekhawat and Dahiya, 1997)**.

2.2 Area and Production

Potato is a crop of considerable importance in the world food production **(Rao, 1998)** and is nowadays the most important and extensively grown horticultural crop in India **(Sikka, 1996)**. The contribution of potato to India's farm economy is manifold. Even though, it is grown on just 0.6 per cent of the total cropped area, its value is estimated to be Rs. 3904 crores, about 1.8 per cent of the total output from agriculture during 1994-95 **(Shekhawat and Dahiya, 1997)**.

Potato is widely adaptable and hence provides flexibility in production. It does not affect other major food crops and gives high production per unit area and time. Potato has also excelled the cereal crops such as rice and wheat by registering higher growth rates during the last four decades. Being a short duration crop it fits into several multiple, relay and intercropping systems, thereby increasing the production **(Shekhawat and Ezekiel, 1999)**.

During 1949-50 to 1997-98 the annually compounded growth rates of production, area and average yield of potato in India were 5.96, 3.51 and 2.37 per cent respectively as compared to 0.64, 0.06 and 0.70 per cent worldwide, respectively. The production, area and yield increased by 11.4, 5.2 and 2.2 times respectively. The 5.96 annual increase in potato production can be compared to 5.50 per cent for wheat, 2.77 per cent for rice and 2.72 per cent for total foodgrains in the same period **(Shekhawat, 1999)**.

Production of potato has made very significant progress during recent years. At present, among the major food crops of the world, the potato ranks fourth after wheat, maize and rice in global production and in root crops, it tops the list **(Grewal, 1993; Rao, 1998; Ezekiel *et al.*, 1999)**. Potato production represents roughly half of the world's annual output of all roots and tubers **(Shekhawat, 1999)**. An analysis of the progress of agriculture and the agriculture-based allied sector shows that despite a dismal food grain production (193.12 million tonnes in 1997-98, a short of 6.88 million tonnes than the target of 200 million tonnes), the production of prominent tuber crop, `potato', was all time high and was 62.3 lakh tonnes more than the production of the year, 1996-97 **(IFD, 1999)**. The national yield of 17 t/ha is higher than the world average of 15 t/ha **(Shekhawat and Dahiya, 1997)**.

Potato is among the ten major food crops of the world and is grown in about 140 countries which is over 70 per cent of the countries in the world. India has the distinction of ranking fourth in its production as well as area earmarked for cultivation in the world, after China, Poland and USA. Moreover, potato has the distinction of occupying the largest area under any single vegetable in the world and represents about 47 per cent of the total tuber crops produced **(Rao, 1998)**. It also ranks number one in terms of yield among all vegetable crops **(Talley *et al.* 1984)**.

Potatoes are grown in India in almost all the states and under diverse agro-climates. In India, nearly 82 per cent of potatoes are grown in the plains, 10 per cent mainly in hills and almost 8 per cent in the plateau regions of south-eastern, central and peninsular India **(Sikka, 1996; Lal *et al.*, 1999)**. The Indo-Gangetic region-Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal and the union territory of Delhi – is the potato bowl of the country, besides north, north-western, north-eastern hills and in plains in different seasons, thereby producing potato in the country all the year round in one part or the other **(Chadha, 1994)**.

By 1996-97, the area for potato cultivation increased to 1.49 million hectares and the production to 28.70 million tonnes with an average yield of 19.2 t/ha. Using the current growth rate for increase in per hectare yields, it has been projected that the national average yield would be 24.54 t/ha and production around 49 million tonnes by 2020 **(Shekhawat and Ezekiel, 1999)**.

Potato produces more food per unit area and time and can substantially supplement food needs of our country. Not only the total yield and average yield per kg/ha/day is more in potato when compared to rice, wheat or maize (Table 2.1) but also dry matter and proteins 1 kg/ha/day are also more than other major crops (Table 2.2) **(Chadha, 1994).**

Table 2.1 : Yield of potato and other major crops

Crop	Yield (t/ha)	Average yield (kg/ha/day)
Potato	12.00	80
Rice	2.00	14
Maize	1.20	9
Soyabean	1.30	13

Table 2.2: Production per unit area per unit time

Crop	Dry matter (t/ha)	Protein (kg/ha/day)
Potato	4.10	2.15
Wheat	1.90	1.52
Rice	1.51	0.89
Maize	1.22	1.33
Soyabean	0.73	2.17

The area, yield and total production in world and India as per the FAO estimates are presented in Table 2.3.

Table 2.3 : Area, yield and production of potatoes

	Year	Area (1000 ha)	Yield (kg/ha)	Production (1000 metric tons)
World	1989-91	17689	15029	265901
	1998	17949	16470	195632
India	1989-91	936	15966	14944
	1998	1500	16710	25065

Source : FAO Production year book (1998).

The substantial gap between present consumption levels in the developed countries (65-95 kg/capita/year) and developing countries (15-25 kg /capita/year) reflects the potential for future expansion of potato consumption in developing areas of the world **(CIP, 1984)**. Amount of potatoes necessary to satisfy half a human's daily need is 1.8 kg and daily intake of 150-300 g of potatoes furnish 4-7 per cent of calories required by humans **(Lisinska and Leszczynski, 1989)**. However, the per capita annual consumption in the country is still low which, though, has increased from 9 kg in 1950 to 15 kg in 1980, it is still the same unlike Europe where it is 120.6 kg per capita per year **(Sharma, 1987; Ezekiel *et al.*, 1999)**.

However, being a risk-prone crop requiring heavy input use and problems of its semi-perishable nature, transportation and storage require precise policy formulation and timely action to sustain production and thereby, help in solving the food shortage problems **(Lal, 1980; Shekhawat and Dahiya, 1987)**.

2.3 Nutritional value and biochemical composition of potatoes

Potato, a major vegetable crop in many parts of the world and a staple food for man in some parts, containing superior nutritional qualities are consumed by a high proportion of the population **(Rao, 1998)** because of their composition, technological versatility and low price **(Chalom *et al.* 1995)**. The food composition of potato, as compared to wheat, maize, rice and tapioca is presented in Table 2.4 **(Gopalan *et al.*,1999)**.

In India, potato is used almost in every type of vegetable to make them palatable. Potatoes mixed with cereals and legumes produce acceptable food products. Moreover, potatoes can be consumed in various forms as boiled, fried, roasted, toasted, baked, steamed and even in processed forms as french fries, chips, flakes, granules, flour etc. Potatoes are versatile as well as unique in the sense that they can fit into any meal and are good for breakfast, lunch or dinner **(Shekhawat and Ezekiel, 1999)**.

The biochemical composition of potato tubers are summarized in table 2.5. Potatoes contribute significantly to the nutritive value of a meal. They contain good quality edible protein, dietary fiber, several minerals and trace elements, essential vitamins and little or negligible fat **(Woodward and Talley, 1953; CIP, 1984; Chadha, 1994; Chalom *et al.*, 1995; Shekhawat and Ezekiel, 1999)**. The potato tubers are considered a well balanced food with regard to ratio of protein to calories **(Sikka, 1996; CIP, 1984)**. However, unlike cereals and pulses, potato contains much greater amounts of water and lower quantities of carbohydrates. As seen from the Table 2.6, one hectare of potatoes can support more number of people per day in terms of major nutrients **(Chadha, 1994)**.

Table 2.4 : Food composition of potato, wheat, rice, maize and tapioca (per 100 g of edible portion)

Particular	Potato	Wheat	Rice	Maize	Tapioca
Moisture (g)	74.70	12.80	13.70	14.90	59.40
Protein (g)	1.60	11.80	6.80	11.10	0.70
Fat (g)	0.10	1.50	0.50	3.60	0.20
Carbohydrates (g)	22.60	71.20	78.20	6.62	38.10
Energy (K cal.)	97.00	346.00	345.00	342.0	157.00
Calcium (mg)	10.00	41.00	10.00	10.00	50.00
Phosphorus (mg)	40.00	306.00	160.00	348.0	40.00
Iron (mg)	0.48	5.30	0.70	2.30	0.90
Carotene (μg)	24.00	64.00	0.00	90.00	0.00
Thiamine (mg)	0.10	0.45	0.06	0.42	0.05
Riboflavin (mg)	0.01	0.17	0.06	0.10	0.10
Niacin (mg)	1.20	5.50	1.90	1.80	0.30
Vitamin C (mg)	17.00	0.00	0.00	0.00	25.00

Source : Gopalan *et al.* (1999).

Table 2.5 : Biochemical composition of potato tubers

Author	Dry matter (%)	Carbohydrates ((%)	Total starch (%)	Moisture (%)
Anderson and Bridges (1988)	-	-	-	-
Augustin *et al.* (1978)	-	-	-	-
Augustin *et al.* (1975, 78, 79)	-	-	-	-
Bajaj (1987)	20-30			70-80
Beukema and Vanderzaag (1979)	90.60-21.30			
Burton (1966)	20-23			
Burton (1989)				
Chalom *et al.* (1995)				81.90
Cieslik (1994)				
Gahlawat and Sehgal (1998)			6	
Gueler and Kolsarici (1995)		6.49-13.49*		
Horton and Sawyer (1985)				
Kaldy and Markakis (1972)				
Karrika *et al.* (1944)				
Khan *et al.* (1997)			9.17-14.48*	77.30-87.20
Lisinska and Laszczynski (1990)			8.0-24*	77.30-87.20
Marwaha (1987)			12.30-18.30*	
Marwaha *et al.* (1998)	18.60			
Marwaha (1999)	16.70-20.7			
Nanda and Khanna (1988)		81.16		
Pant and Kulshrestha (1994)	17.30-21.45		9.27-15.21*	
Peshin (1998)	16.50-24.4			
Rao (1998)			60-80	
Reust *et al.* (1993)			12-15.9*	
Sandhu *et al.* (1987)				
Schwimmer and Burr (1967)				
Shekhawat and Ezekiel (1999)	20		80	
Sikka (1996)	19-23			
Sauthgate and White (1981)				
Sun *et al.* (1995)				
Swaminathan and Pushkarnath (1962)			14.70-18.80	
Talburt and Smith (1987)			60-80	
Temple *et al.* (1991)		854 g/kg		
Trehan and Sharma (1996)				
Verma *et al.* (1975)	18.8-21.70			
Waghmare *et al.* (1999)				80.45-81.2

	Minerals (mg/100 g)									Vitamins (mg/100		
	Ca	P	Fe	Mg	K	Zn	Cu	Mn	C	B_1	B_2	Niacin
Anderson and Bridges (1988)												
Augustin *et al.* (1978)									76.80 - 179.40	0.31 - 0.45	0.14-0.33	5.10-10.50
Augustin *et al.* (1975, 78, 79)									9-33*			
Bajaj (1987)									20*			
Beukema and Vanderzaag (1979)												
Burton (1966)												
Burton (1989)												
Chalom *et al.* (1995)									9-33*			
Cieslik (1994)									9-33*			
Gahlawat and Sehgal (1998)												
Gueler and Kolsarici (1995)												
Horton and Sawyer (1985)												
Kaldy and Markakis (1972)												
Karrika-*et al.* (1944)									9-33*			
Khan *et al.* (1997)	5.66-8.70*	29.80-49.00*							9-33*			
Lisinska and Leszczynski (1990)												
Marwaha (1987)												
Marwaha *et al.* (1998)												
Marwaha (1999)												
Nanda and Khanna (1988)	34.20	184.54	4.46						91-04			
Pant and Kulshrestha (1994)												
Peshin (1998)												
Rao (1998)												
Reust *et al.* (1993)												
Sandhu *et al.* (1987)									9-33*			
Schwimmer and Burr (1967)												
Shekhawat and Ezekiel (1999)									20*			
Sikka (1996)												
Sauthgate and White (1981)												
Sun *et al.* (1995)												
Swaminathan and Pushkarnath (1962)												
Talburt and Smith (1987)									20*			
Temple *et al.* (1991)			25.6 mg/kg				5.0 mg/kg	10 ml/kg				
Trehan and Sharma (1996)	22-60	246	53 ppm	113 - 168	1663-2063	10-18 ppm	2 t-4.3 ppm	5-31 ppm				
Verma *et al.* (1975)												
Waghmare *et al.* (1999)									9-33*			

* = Fresh weight basis

Table 2.6: Number of people which one hectare can support per day in terms of major nutrients

Crop	Energy	Protein	Ascorbic acid	Iron
Potato (16 t/ha)	35	64	711	86
Cassava	17	8	343	29
Rice	21	28	0	4
Maize	13	25	0	31

Potato is a wholesome, nutritious and low energy food as compared to other cereals and staples, roots and tubers (**Horton and Sawyer; 1985)**. Starch is the basic component, providing the major amount of energy obtained by potato consumption. Gelatinized starch in freshly cooked potatoes is rapidly digested and has low energy content than raw cereals and legumes. Even cooked potatoes have a lower calorific value than cooked cereals and pulses **(Chadha, 1994)**.

Potatoes yield about 97 K cals per 100 g on fresh weight basis which is less as compared to other cereals and legumes **(Gopalan *et al*, 1999)**. Also, the yield of energy per unit of land space is high for potatoes, being almost twice the food energy produced per unit of land in comparison to wheat **(Chadha, 1994)**.

Contrary to the common conceptions, potatoes contain negligible fat (0.1 per cent) and low in energy, but in fried or processed forms in which fat has been added, they become energy rich. Thus, the fat absorbed during frying is the real culprit to cause obesity and rules out the misconception that potatoes cause obesity **(Shekhawat and Ezekiel, 1999)**. A boiled potato provides about 69 K cal. Per 100 g consumed **(Shekhawat and Ezekiel, 1999)** as compared to 220 K cal for fresh fried products and 568 K cal for chips for the equivalent amount **(Watt and Merill, 1963; Bajaj, 1987)**. Potatoes can therefore be effectively used in diets for gaining or losing weight, depending on the cooking and processing which would determine the quantity of moisture and fat in the final product.

2.3.1 Dry matter

Potato is an efficient crop capable of producing over twide as much dry matter as the cereals per unit of land and time **(Sikka, 1996; CIP, 1984)**.

Ifenkewe and Allen (1978) reported that the dry matter content of potato varies considerably among varieties and was also influenced by the environmental conditions of cultivation and cultural practices **(Bajaj, 1987)**. **Ifenkewe and co-workers (1974)** showed an increase in the dry matter content of potatoes with reduction in tuber size. According to **Kolbe (1995)** and **Beirne (1990)** climatic conditions and fertilization influence the dry matter content and starch content of potatoes and that a cool, but sunny location facilitates high potato yields with high dry matter and starch contents.

Dry matter content determines the raw potato texture as well as yield and texture of the processed potato products **(Verma *et al.*, 1975; Marwaha, 1997)** and is one of the major factors which decides the suitability of a potato variety for processing into different forms **(Talburt and Smith, 1987; Burton, 1989; Marwaha, 1997)**.

Grewal and Uppal (1989) also reported that potatoes with high dry matter resulted in high yield of dehydrated products and lower uptake of oil. According to **Potato Marketing Board (1971)** tubers of cultivars having low dry matter content are suitable for canning and with high dry matter ones are good for processing into chips and other dehydrated forms. Similarly, **Brody (1969)** reported that potatoes having more than 20 per cent dry matter are good for chips and french fries and **Gould (1986)** reported a dry matter content of 21.2 per cent as ideal for chips. Potatoes having high dry matter content are considered suitable for the preparation of french fries and chips since this parameter is associated with the mealiness, crispness, rigidity and reduced oil uptake in french fries **(Kirkpatrick *et al.*, 1956)**.

2.3.2 Carbohydrates

The main carbohydrates in potatoes are starch and sugars. Starch is the major portion, constituting 60-80 per cent of the dry matter content and is composed of amylose and amylopectin in a 3:1 ratio **(Talburt and Smith 1987; Rao, 1998)**. The sugar content is about 10 per cent of the dry matter content as observed by **Barkar (1938)**. The major sugars of potato are glucose, fructose and sucrose and usage of tubers containing more than 2 per cent reducing sugars like glucose and fructose may level to dark colouration of chips occurring to maillard reactions and hence are not considered to be good for processing **(Rao, 1998)**. An important factor apart from maturity, influencing sugar content of potatoes is temperature during post harvest storage **(Talburt and Smith, 1987)**.

2.3.3 Total starch

Starch is the major carbohydrate of potato, constituting 60-80 per cent of the dry matter **(Rao,1998)**.

Haase and Plate (1996) showed that the starch content of potatoes was influenced by the varieties as well as by environmental conditions.

Kirkpatrick and co-workers (1951); Roberts and Procter (1955) and Unrau and Nylund (1957) reported that low starch content of potatoes resulted in sogginess, while its high percentage caused sloughing during boiling that resulted in mealiness of potatoes after cooking. According to **Pruthi (1978)** high starch containing varieties were suitable for drying purposes. Starch content of the same tuber determines the texture of the processed product and high starch content is associated with the mealiness **(Marwaha, 1987)**.

2.3.4 Moisture

Potatoes contain about 80 per cent water and 20 per cent dry matter **(Shekhawat and Ezekiel, 1999)**.

2.3.5 Nitrogenous constituents

Potato is considered to be low in protein on fresh weight basis (2 per cent), as compared to cereals, however, on dry weight basis, the quantity is about as much as in the cereals **(Verma, 1977)**. The protein content of potato is equally to that of yam and almost twice that of sweet potato and cassava **(CIP, 1984)**.

Mulder and Bakema (1956) found considerable varietal differences in the contents of protein and soluble non protein nitrogen. These varietal variations in the protein content were explained on the basis of genetic variations **(Smith, 1968)**. **Ciecko (1974)** found that nitrogen fertilization increased the content of total, non-protein and in some varieties protein nitrogen of potato.

It was found that the method of cooking also influenced the protein and amino acid content of potatoes. **Chaudhuri and co-workers (1963)** found an increase in the protein content following baking and frying and reported it to be due to a concentration effect. Protein losses in various foods have been reported to occur during processing, due to maillard reactions in which amino acids react with sugars at high temperatures producing brown melanoidins **(Reynolds, 1965)**. However, **Bonchev (1965)** in Germany found that although steaming and baking caused no changes in the total protein and amino acid contents of potato, frying caused reduction. Cystine, glutamic acid, tryptophan and tyrosine were the most sensitive to heat treatment and arginine, aspartic acid and threonine the most heat resistant.

Potatoes are good sources of high quality protein with a biological value higher than the major cereals and proteins of animal origin like milk and beef **(Shekhawat and Ezekiel, 1999)**. Biological value (which is the portion of the nitrogen retained in the body) is 73 for potato as compared to 54 for rice and 53 for wheat and is next only to egg protein **(Sikka, 1996)**. **Johnson and Lay (1974)** rank potato protein next to soyabean protein in US production and its biological value is equal to that of soya protein **(Rao,1998)**.

Apart from this, the advantage that potato protein has over other cereal proteins is its balanced amino acid content which can meet the needs of infants and small children **(Rao, 1998)**. Its high lysine content can thus supplement diets, limiting in lysine such as cereal based diet which are limiting in lysine **(Ponnampalam and Mondy, 1983; Shekhawat and Ezekiel, 1999)**. Besides, high lysine content, the potato protein is moderately limiting in the sulphur containing amino acids – methionine and cystine **(Table:2.7). Scrimshaw and Young, 1976)**.

Table 2.7 : Essential amino acid content (g/100 g protein)

Amino acid	Potato	Maize	Rice	Wheat
Arginine	4.60	6.50	8.20	4.30
Histidine	1.50	3.00	2.40	2.10
Leucine	10.40	13.60	13.00	10.30
Lysine	6.20	4.70	3.70	2.70
Methionine	2.80	1.90	1.80	1.60
Phenylalanine	4.40	4.80	5.70	4.60
Threonine	4.80	3.90	3.70	2.80
Tryptophan	1.60	-	1.30	1.20

Because of the better balanced amino acid contents of potato protein, it is considered to be nutritionally superior to cereal proteins and is one of the few vegetable proteins comparable with highly valuable proteins of animal origin **(Chadha, 1994)**.

Potatoes have a well balanced protein-to-calorie ratio. Moreover, on cooked basis, the potatoes compare well with other staples, such as boiled rice and cooked cereals such as porridges. Therefore, if enough of potato is taken to supply calories, a significant quantity of protein will also be provided **(CIP, 1984; Horton and Sawyer, 1985)**.

The amino acid score of potato is similar to that of cereals. The protein score of 70 can be compared with 75 for sweet potatoes and rice and score of 40 to 60 for wheat, maize, beans and peas. Even a small quantity (100 gms of boiled potatoes) supplies upto 30 per cent of the FAO/WHO recommended daily allowance of protein for children and upto 7 per cent of the adult **(Mica, 1969; CIP, 1984; Horton and Sawyer, 1985; Bajaj, 1987)**.

2.3.6 Fat

Potatoes almost totally lack fat – a substance with twice the calorific value of carbohydrates **(Lisinska and Leszczynski, 1989)**. **Smith and Laura (1969)** analysed the fatty acid composition and reported that 60 per cent are unsaturated. According to **Rao (1998)**, linoleic, linolenic and palmitic acids are the major fatty acids and a number of organic acids present in potato in varying amounts contribute to its flavour. Thus, whatever fat is present in potato, is nutritionally good **(Verma, 1977)**.

2.3.7 Total ash

Burton (1989) reported that the ash content (inorganic residue remaining after incineration) of the tubers is influenced by the use of fertilizers and metal containing fungicides. The inorganic constituents of potatoes varied with variety and cultural practises **(Smith, 1968)**.

2.3.8 Minerals

Potatoes are reported to contain a large amount of minerals **(Burton, 1966)**. Minerals and trace elements in the potatoes provide a good source of potassium, phosphorus and magnesium and a moderate source of iron, zinc, calcium, manganese and a low sodium content which is of use in salt-free diets **(CIP, 1984; Talburt and Smith, 1987; Ereifej *et al.*, 1998)**. The low percentage of phytic acid in tubers does not affect the availability of minerals such as calcium, phosphorus and iron and almost all of it is available to human beings **(Nagaich, 1977; Chadha, 1994; Trehan and Sharma, 1996)**.

The potassium concentration in potatoes being higher (1663 to 2063 mg/100 g) than that of cereals (200 to 880 mg/100 g) can, therefore, be used in diets of patients with high blood pressure (high potassium : low sodium) as well as reduce the incidence of hardening of arteries and heart ailments **(Trehan and Sharma, 1996)**.

Wide variations in mineral content of potatoes have been attributed to the differences in soil type, mineral content of the soil and varietal differences **(Augustin, 1975)**. **True *et al.* (1979)** found that cooking had a negligible effect on mineral content of potato flesh regardless of whether the potatoes were boiled with or without skin or baked in a conventional or microwave oven. They further concluded that a 150 g serving of fresh potatoes furnish 10 per cent of the U.S. RDA for iodine, 8 per cent for copper and magnesium, 6 per cent for phosphorus and 2 per cent for iron and zinc.

According to **Chadha (1994)** 100 grams of boiled potatoes can supply 7 per cent of the daily requirement of phosphorus for both children and adults and 150 grams of boiled potatoes provide 6-10 per cent of daily requirements of magnesium. Potatoes (100 grams) can also provide about 83 per cent of adult and 30 per cent of child's requirement for iodine and 2 to 4 per cent of zinc requirements.

In addition to their good nutritional qualities as discussed, potatoes can be abundantly, quickly and economically produced. With these added benefits, potato, can therefore be regarded of high nutritive value, suitable for consumption in various ways.

2.3.9 Vitamins

Potatoes contain substantial quantities of vitamins B and C. B group vitamins present in potatoes include thiamine, riboflavin, niacin, pyridoxine and folic acid. Potatoes also contain vitamin C, which is totally lacking in cereals **(CIP, 1984; Horton and Sawyer, 1985; Bajaj, 1987; Talburt and Smith, 1987; Sikka, 1996; Rao, 1998; Shekhawat and Ezekiel, 1999;)**.

Losses of vitamin C occur during long-term storage and cooking **(Rao, 1998)**. **Swaminathan and Gangwar (1961)** observed that considerable quantities of vitamin C of the potato tubers were lost during cooking and that the losses of vitamin C were lowest (15-17.3 per cent) when unpeeled potatoes were boiled, but frying in fat resulted in very high losses (55.3-58.2 per cent). They also suggested that the extent of loss of vitamin C in potatoes is dependent on the temperature and duration of cooking. According to **Misra (1987)** the three methods of cooking i.e. boiling, pressure cooking and baking all resulted in significant loss of vitamin C. The loss of vitamin C during pressure cooking was lowest (5.90 per cent) and highest (15.50 per cent) during baking. Vitamin C content was recorded as 23.54 mg/100 g for raw, 20.35 mg/100 g for boiled and 19.89 mg/100 g for baked. Talburt and Smith, 1987 quoted that storage condition as well as methods of cooking, processing and preparation for eating also markedly affect the vitamin C content of potatoes.

It has been estimated by **Smith and Laura (1969)** that in U.S.A. potato can meet 9.5, 8.1, 2.7, 28.5 and 50 per cent of the R.D.A. of niacin, thiamine, riboflavin, pyridoxine and vitamin C, respectively for an adult.

2.3.10 In-vitro protein digestibility

Ravindran and co-workers (1995) recorded the mean in vitro protein digestibility of sweet potato cultivars as 75.8 per cent, which is more than that of potatoes (68.06 per cent) and indicates that sweet potato protein is well utilized. **Oyenuga and Fetuga (1975)** suggestged that peeling significantly increased the digestibility of crude protein in sweet potatoes, but not in cassava.

2.3.11 Dietary fiber

Dietary fiber has emerged as a leading dietary factor in the prevention and treatment of chronic diseases. High fiber intakes are associated with lower serum cholesterol concentrations, lower risk of coronary heart disease, reduced blood pressure, enhanced weight control, better glycemic control, reduced risk of certain forms of cancer and improved gastrointestinal function. Dietary fiber can be categorized into water-soluble and water-insoluble components and the recommended intake for healthy adults is 40 g/day **(Gopalan *et al.*, 1999)**.

The non-starch polysaccharides such as cellulose, hemicellulose and pectin constitute about 1-2 per cent and contribute to the final texture of cooked potato and also act as a source of dietary fiber **(Rao, 1998)**.

2.4 Storage of potatoes

Potatoes are grown in larger quantities by farmers, but because they are seasonal, they have to be stored for use throughout the year **(Nanda and Khanna, 1998; Ezekiel *et al.*, 1999)**. Potato tubers immediately after harvesting loose water three times faster than they do after a month of storage. Such a great difference is due to the potato skin, which is thin after harvest and loosely bound with the flesh, but after a preliminary period of storage, the skin is covered with a cork layer which retards water evaporation. Water evaporation from the tubers during storage accounts for the qualitative loss and detrimental changes in potato consistency **(Lisinska and Leszynski, 1989)**.

The losses due to poor storage and distribution system have been reported as 12 per cent by **CIP (1984)**, 10 per cent by FAO and loss in excess of 20 per cent have been reported in many places **(Horton and Sawyer, 1985)**. As perishability is more specific to potato tubers, quick transportation of the crop from production area to the consumption centres is an important factor which influence the price and supply of the crop. With proper storage facilities, efficient transport and marketing arrangements, it shall be possible to bring about a fair equilibrium between demand and supply **(Shekhawat and Ezekiel, 1999)**. In the absence of proper storage facilities, the prices tend to be high during the off-season. Storage, therefore, helps in regulating the supplies to the market and thus avoiding gluts and distress sale by the growers. Furthermore, it reduces the transport bottleneck at the peak period **(Ezekiel *et al.*, 1999)**. In order to avoid these problems, it is essential that cold storage facilities and other storage facilities be made available **(Sangwan, 1991; Shekhawat and Dahiya, 1997; Ezekiel *et al.*, 1999)**.

Potatoes may start sprouting within 2 to 3 months of harvest even when stored at temperature slightly above 5°C **(USDA, 1977)**. The sprouting of tubers causes lower market value for table purposes **(Lal, 1980; Ezekiel *et al.*, 1999)**.

Indigenous potato storage technology needs to be refined and developed on area specific basis and priority so that farmers can store surplus produce for 3-4 months soon after harvest **(Shekhawat and Dahiya, 1997)**. Storage of potatoes at low temperature (3-4°C) under tropical conditions is one of the most suitable technique **(Bansal, 1986)**. Studies done at CPRI have shown that table and processing potatoes be stored at 8-12°C, after treating the potatoes with a sprout suppressant. However, for short term storage of table and processing potatoes for 3-4 months i.e. upto June end, non-refrigerated storage methods like evaporatively cooled potato store and traditional on-farm potato storage methods like heaps and pits can be used profitably, with no investment on storage structures **(Ezekiel *et al.*, 1999)**.

In India, potatoes are mostly stored in cold stores maintained at a temperature of 2-4°C and at about 95 per cent relative humidity **(Ezekiel *et al.*, 1999)**. Potatoes can be stored for 6 to 8 months in cold storage, but as the cold storage rentals have gone up considerably, it has affected the returns to the growers, making potatoes costlier for consumers. Moreover, cold storage is not suitable for potatoes as cold stored potatoes, which become sweet due to sugar accumulation are not preferred both by the consumers and processor. Even, when the potatoes are taken out of the cold storages, they sprout, which reduces their value for consumption. In fact construction of cold stores with storage temperature in the range of 10-12°C will be better as it would save on energy and tubers remain fit both for consumers as well as processors **(Shekhawat and Dahiya, 1997)**. The potatoes can be stored only for a limited period in cool stores or ordinary farm store, after which there are high weight losses and become unfit for processing **(Mehta and Kaul, 1988; Marawaha, 1996a)**.

The cold storage facility is available for only 46 per cent of the total potato production as against the ideal requirement of 50-60 per cent **(Shekhawat and Dahiya, 1997)**. At present, the available capacity for storage is inadequate and is only 9 million tonnes as against the 28.7 million tonnes of potato produced **(Shekhawat and Dahiya, 1997; Shekhawat and Ezekiel, 1999)**. Besides this, the cold storage facility is handicapped by power shortage as well as monopoly to a large extent by the traders. At present, there are 3443 cold store units in our country and out of this, 2975 are in the private sector, 303 in co-operative sector and remaining in public sector **(Ezekiel *et al.*, 1999)**.

Simple storage technology is emphasized to overcome the losses due to sprouting, during storage at room temperature for 4 months as well as tuber rottage due to problems of cold storage **(Lal, 1980)**. Simple post harvest processing of the bulky, perishable, fresh potato tubers into the dehydrated potato products helps to extend the storage life and serve as a means to increase the supply in off-seasons **(Nanda and Khanna, 1998)**.

2.4.1 Changes during storage of potatoes

Porodina and Gab (1993) reported that the storage method affects the quality of potatoes and was found that potatoes stored at 0-1°C and 90 per cent relative humidity for 6 months in polyethylene packages had reduced sugar losses, lowest starch hydrolysis, lowest moisture loss and low vitamin C losses.

Five Indian potato cultivars were stored for 180 days (6 months) at 27-32°C with 60-80 per cent relative humidity, at 15°C with 80-85 per cent relative humidity and at 2-4°C with 90 per cent relative humidity the normal conditions for commercial cold storage. Sugar contents generally tended to increase during storage (greatest at 2-4°C) and vitamin C retention was also less **(Joshi *et al.*, 1990)**.

Takahata *et al.* (1995) studied the changes in carbohydrates during storage of sweet potatoes at 12-16°C upto 138 days. After the storage period, sweet potatoes showed high levels of sucrose, dextrin and decreased starch content, which shows the role of alpha-amylase in starch degradation and the possible role of sucrose synthase in sucrose accumulation.

The storage of potatoes for 4 months resulted in a sharp decrease in ascorbic acid, significant decreases in niacin and folic acid and vitamin B6. Prolonged storage had little overall effect on thiamine and riboflavin **(Augustin *et al.*, 1978)**.

Variations in ascorbic acid levels during storage, range between approximately 26 mg/100 g at the beginning of storage upto 9 mg/100 g after 6 months of storage **(Augustin *et al.* 1975)**. A loss of 10-22 per cent in ascorbic acid content in potatoes was reported during first month of storage **(CPRI, Annual Report, 1980)**. According to **Augustin (1975)**, the ascorbic acid content in potatoes decreases with progressing storage time, with the largest decrease being during the early part of the storage period.

Commercial cold storage of potatoes at 2-4°C and relative humidity 90-95 per cent extended their shelf life for 6 to 8 months, but vitamin C levels suffered more losses than those kept at ambient or 10-20°C storage **(Joshi *et al.*, 1990)**.

Dutch potatoes of different potato varieties, stored for 8 months at 5-6°C and 95-98 per cent relative humidity were analyzed for ascorbic acid and dehydro ascorbic acid. The amount of dehydro ascorbic acid was negligible, whereas, total loss of ascorbic acid ranging from 21 to 60 per cent was most rapid during the first four months of storage and gradual over the rest of the period **(Keijbets and Ebbenhorst, 1990)**.

The dry matter content also remained almost the same during the period of storage **(Kumar *et al.*, 1999)**.

2.5 Processed products from potato

2.5.1 Processing of potatoes

Potato processing is a very old method and has been practised in the highland areas of Peru and Bolivia for atleast 2000 years. In

India, the first attempt to process potatoes on a commercial scale, started in 1991, to produce potato meal **(Marwaha, 1997)**.

At present, processing is a fast growing sector within the world potato economy. Currently, about half of the annual crop in USA is processed and in India, processing of potatoes constitutes less than 0.5 per cent of the total annual production. In India, many processing plants with an annual capacity of 25,000 tonnes have been installed and now it may have increased to about 50,000 tonnes/annum **(Marwaha, 1997)**. Industrial manufacturing of processed potatoes seems to be only in its infancy in most of the developing countries with the exception of China, Korea and Mexico is confined mainly to the developed countries **(Holm *et al.*, 1994; Marwaha, 1997)**. However, fast growth in potato processing is expected to occur in India due to increased urbanization, preference of new generation for easy-to-prepare and fast foods, rising per capita income, increase in number of working women and expanding tourist trade. Among the processed potato products, chips and French fries are the most popular forms in different countries. With the entry of multinational companies in the processing sector in India, the fresh or frozen french fries are likely to be introduced shortly in the market **(Marwaha *et al.*, 1998; Marwaha and Sandhu, 1999; Shekhawat and Ezekiel, 1999)**.

The potato processing industry is primarily concerned with the quality and yield of processed products. The quality of final processed products is determined by the raw material that is, potato and hence

The processing industry requires potato tubers with a high dry matter content, low reducing sugars besides the starch, free amino acids and phenolic compounds of tubers which influence the potato processing quality. The shape, size and colour of the tubers is also taken in consideration **(Marwaha, 1988; Misra and Premchand, 1988; Peshin, 1998; Marwaha, 1999;)**. High dry matter content is associated with mealiness, crispness and reduced oil uptake in fried products as french fries and chips **(Grewal and Uppal, 1989)**. As indicated by **Sukumaran and Verma, 1993**, the raw material requirements for different forms of processed product are not the same. The dry matter content for dehydrated potato products and chips be 22-25 per cent and for french fries be 20-24 per cent. Similarly, starch content varied from 15-19 per cent for dehydrated products and chips and 14-16 per cent for french fries.

Processing of potatoes is an imperative necessity in India to avoid gluts and the consequent difficulty of storing large quantities of potatoes during period of extremely high temperature. Moreover, the abundant solar energy available in the plains can be used in the development of dehydrated products at no extra cost **(Marwaha and Sandhu, 1999)**. According to **Marwaha (1997)** processed potato products can be classified as follows :

1. Fried products which include potato chips, frozen french fries and other frozen products such as potato patties, puffs and rounds and mashed potato.

2. Dehydrated products such as dehydrated chips, dices, waris, flakes, granules, flour, starch and potato custard powder.
3. Canned potatoes.

Processing operations such as drying, frying and canning which involve high temperatures, reduce the levels of amino acids and reducing sugars considerably, but at the same time enhances digestibility of potato starch which is indigestible in the raw potatoes **(Marwaha, 1997)**.

2.5.2 Preparation of potatoes for processing

2.5.2.1 Boiling of potatoes

Boiling is essentially used as a main cooking step in the manufacture of several processed products from potatoes. In order to retain maximum nutritive value, boiling of potatoes with their skin on in water was recommended **(Talburt and Smith, 1987)**. The preferred characteristics of boiled potatoes include mild flavour, firm texture, ability to retain their shape on boiling, easily be broken as such to dry crumbly mass and would have creamy colour **(Burton, 1989)**.

Potatoes with high specific gravity having high dry matter content, low sugar content, espcially reducing sugars are recommended for boiling. Potatoes with high degree of maturity are reported to have these characteristics **(Van Arsdel and Coopley,**

1964; Smith, 1968). Brody (1969) suggested that potatoes with 18.20 per cent of dry matter, 1.071 to 1.080 g/cc specific gravity and waxy texture were good for boiling purposes.

Firmness of boiled potatoes depends on firmness of potato tuber, which ultimately depends on starch content **(Baremore, 1937; Mica *et al.*, 1984)**. The content of starch, pectic substances, dry matter content, mono and divalent ions and cell size of potato tubers were suggested to affect the texture of cooked potatoes **(Burton, 1989; Beirne, 1990)**.

Bursting of potato tubers during boiling is an undesirable characteristic which occurs due to excessive hydration of cell wall material causing intercellular separation and cell disruption **(Hughes *et al.*, 1975; Warren *et al.*, 1975; Roe *et al.* , 1990)**.

2.5.2.2 Peeling losses and yield recovery of processed products

The higher peeling losses of potato varieties were attributed to the smaller tuber size of varieties and were observed as 7 per cent and 9 per cent **(Waghmare *et al.*, 1999)**.

The yield recovery of processed products is directly related to the tuber dry matter content of the variety **(Marwaha, 1999)**. The yield of the dried chips and potato flour was thus related with the high dry mater which resulted in higher product yield. The yield of potato flour was higher, ranging between 20.4 to 24.7 per cent of the fresh weight of tubers processed than chips (14.1 to 18.5 per cent), which was attributed to the high dry matter losses during chip making than during flour-making **(Rai, 1990)**. The final yield of finished french fries from fresh potatoes is in the range of 30-45 per cent **(Marwaha, 1997)** and that of potato meal was between 16-20 per cent **(Rennick, 1911)**. **Hamed *et al.* (1973)** reported the yield of peeled sweet potato flour as 14 per cent.

Peeling losses of potato cultivars varied from 6.73 per cent to 11.03 per cent **(Sandhu *et al.*, 1987; Beerh *et al.*, 1988)** and per cent yield of dehydrated chips on fresh weight basis ranged from 24 to 27 per cent **(Beerh *et al.*, 1988; Waghmare *et al.*, 1999)**.

The potato flour recovery was recorded as 16.6 per cent on fresh weight basis by **Marwaha and Sandhu (1999)**.

2.5.3 Dehydration of potatoes

Dehydration or drying is an important method for preservation of potatoes. Although the term drying and dehydration are used synonymously, the former is often used for drying under the influence of natural forces such as the sun, whereas the latter is used for mechanical methods using hot air, vacuum or infra-red radiation.

Dehydration of products of plant origin is one of the oldest methods used for processing the food destined for longer storage as it results in reduction of water content and thereby prevention of microbial growth **(Lisinska and Leszczynski, 1989).** Dehydrated potato products contained same chemical constituents as fresh potatoes, though their amount varied.

Dehydration is advantageous because it is cheaper and can be done at the level of individual farming families. Moreover, solar energy which is abundant and freely available, can be used for dehydration and dehydrated products require less storage space as compared to a large area required for storing potato tubers **(Shekhawat and Ezekiel, 1999).**

Potato can be dehydrated into various products such as dehydrated chips, dices, flakes, granules, starch and potato flour **(Van Arsdel and Coopley, 1964; Marwaha and Sandhu, 1999; Shekhawat and Ezekiel, 1999).**

However, the dehydrated potatoes are usually lacking in potato flavour **(Fan and Yuch, 1980).** Off flavour and odour in the stored tubers are also attributed to the fact that the raw material used for manufacturing was not selected properly. Bitter flavour of dehydrated product is associated with the solanine, a bitter glycoside present with green spots, sweet flavour due to large amount of sugar or fusty flavour results from bad storage conditions of the raw material **(Wilska and Boruch, 1979).**

Dehydration of potatoes using solar energy has been suggested as a means of coping with the problem of potato storage **(Singh and Verma, 1979).** Solar energy can be utilized by the housewives to dehydrate potato slices, dices, chips, waris and papads etc. **(Marwaha and Sandhu, 1999)**. According to **Verma (1977)** and **Marwaha and Sandhu (1999)**, large sized potatoes having high dry matter and low reducing sugars are suitable for the preparation of chips, french fries, starch, potato flour and other forms of dehydrated products, whereas small potatoes with low dry matter are preferred for canning.

2.5.4 Potato flour

Potato flour is the oldest commercial processed potato product **(Willard and Hix, 1987)**. The name potato flour was given to the product obtained by grinding the dried sliced potatoes **(Rendle, 1945)** and at the time of world war it was offerred to the public as a substitute of wheat flour **(Noel, 1922)**.

Variety of process have been used for the manufacture of flour from potatoes **(Sapers *et al.*, 1973; Vaidehi and Sunanda, 1982; Kulge *et al.*, 1985)**. One of the simplest ways of preparing raw dried potato flour was to grind the potatoes in hammer mill, drying in a steam tube drier and finally grinding to flour but elimination of cooking does not cause inactivation of enzymes **(Eskew and Edwards, 1950; Edwards and Hoersch, 1952)**. **Nanda and Khanna (1988)** suggested that instead of slicing, boiled potatoes can be grated and sun dried prior to grinding to flour. **Singh (1993)** gave the method of boiling potatoes, peeling, grating, drying and then packaging in polyethylene bags, for the production of potato flour.

According to **Marwaha and Sandhu (1999)** potato flour production involves peeling, washing, cutting, dipping in 0.25 per cent sodium metabisulphite and pressure cooking for 10 minutes. The cooked pieces were then dried in oven at 60°C. The dried product was ground into fine flour by using a grinding mill.

The most simple and widely used procedure for potato flour preparation consists of dehydrating potatoes in the form of slices and then grinding to make flour. On commercial scale, it is made by drying the boiled and mashed potatoes in a roller drier **(Srivastava *et al.*, 1973)**. **Pant and Kulshreshtha (1995)** prepared potato flour from six potato varieties by pressure cooking the potatoes at 10 lb/cubic inch for 22 minutes, cooling under running water to room temperature within 3 minutes and further drying in a cabinet drier at 60°C.

Further work conducted at the Central Potato Research Station, Jalandhar during 1995-96, showed that the recovery of potato flour from three Indian varieties was quite high, when prepared by drying the boiled mashed potatoes than by drying the blanched slices.

In a study by **Rai (1990)**, as solar energy is abundant in the country, especially in the post-harvest months, that is, February-May when humidity is also low (<20 per cent) the production of potato flour and chips by solar dehydration is possible, and may be adopted as on-farm or cottage level activity.

Processing potatoes into flour is perhaps the most satisfactory method of creating a product that is not only nutritionally adequate, but also remain for an extended period without damage, requires less rigorous storage control than raw tubers and have low storage density **(Hadziyev and Steele, 1979)**.

Potato flour is now a days being widely used by the food industries, especially the baking industry, but its use in home cooking is still very less **(Talburt and Smith, 1987)**. Potato flour finds immense use in bread making, where it helps to retain the freshness of bread, imparts distinctive flavour, improves toasting quality and crust colour **(Rao, 1998; Marwaha and Sandhu, 1999)**. Besides this, potato flour is used in other snack foods, in combination with different types of flour, other bakery items, as a thickener in several food items etc.

2.6 Physico-chemical characteristics of potato flour

2.6.1 Colour

The colour of the potato flour is affected by the colour of the flesh and moreover by the heat damage during the processing **(Olson and Harrington, 1955; Lisinska and Leszczynski, 1989)**. According to **Pant and Kulshreshtha (1995)** potato flour of the six potato varieties varied from pale yellow – 5y (8/4); 5y (3/4), 2.5y (8/4) to yellow – 2.5y (7/8).

2.6.2 Water absorption capacity

Water absorption by the flour, which affects the texture of the reconstituted product, depends on the number of the ruptured cells in the flour. The number of the ruptured cells can be controled by monitoring the dehydration steps as the cell rupture has been reported to occur during dehydration **(Bunimovitch and Faitelowitz, 1936; Olson *et al.*, 1953; Olson and Harrington, 1955; Nowotny, 1969). Willard and Englar (1959)** investigated the effect of granulation, cooking time and solid content of raw potatoes on water absorption by potato flour. They found that viscosity was increased with increase in grain size, decreased with increase in cooking time and further observed increased viscosity of potato powder made from potatoes containing low solid contents. **Pant and Kulshreshtha (1995)** reported that the water absorption capacity of potato flour varied from 35.33 per cent to 46.00 per cent in six potato varieties. This could be attributed to varietal differences in free starch levels and composition of starch **(Purves and Scrively, 1975). Katara (1983)** studied water absorption of potato flour made from different potato varieties. He observed 423 to 453 per cent of water absorption by potato flour and thus established a direct relationship between water absorption capacity and starch contents of potatoes.

2.6.3 Moisture sorption isotherm

Hygroscopicity is a fundamental characteristic of biological material. When such materials are exposed to a given atmosphere, they have a tendency to loose or gain moisture depending on its temperature and relative humidity. The relative humidity of an atmosphere in equilibrium with a product increases with the moisture content of the product until saturation of the atmosphere **(Hunt and Pixton, 1974)**. In other words, the material tries to attain equilibrium. The process in which the hygroscopic material looses or gains moisture is called sorption, whereas plot of equilibrium moisture content (EMC) verses relative humidity at a given temperature is termed as sorption isotherm. The sorption isotherm is the most useful way of presenting water activity data and also of particular importance in the design of a food dehydration process, especially in the determination of a drying end point which ensures economic viability and microbiological safety **(McLaughlin and Magee, 1998)**.

The sorption isotherm of a food material is best described as a plot of the amount of water adsorbed as a function of the relative humidity. This amount of water is that which is held after equilibrium has been reached at a constant temperature **(Labuza, 1968)**. There is a relationship between equilibrium moisture content and equilibrium relative humidity in sorption, isotherm. According to **Rockland and Hishi (1980)** sorption isotherm is best represented by a sigmoid curve. In the low humidity range, the curve is concave to the humidity axis representing desorption, in the mid-range it has a region of inflation which is approximately linear suggesting an increase in moisture content and in the high humidity range, the curve is concave to the moisture axis suggesting adsorption phenomenon. Conditioning flours by absorption of water vapour from saturated atmospheres is an important step common to processing of many flour based foods. In addition, such an absorption process is also important from the view point of flour storage **(Hunt and Pixton, 1974)**. **Labuza (1968)** suggested that sorption isotherm was developed by exposing dry material to various relative humidity and measuring change in weight due to sorption/desorption of water. He further divided sorption isotherm into 3 regions depending on the state of water present in it viz. monomolecular film of water, multilayer films and condensation of water in the capillaries.

2.6.4 Particle size index

Particle size index (PSI), which is inversely related to fineness of flour, also affects water absorption capacity **(Khan *et al.*, 1982)**. A significant positive correlation was found between water absorption and PSI and particle size index in potato flour ranged from 32.08 to 36.02, in six potato varieties **(Pant and Kulshreshtha, 1995)**. Water uptake was also related to the particle size, which in turn was affected by the cell size **(Olson and Harrington, 1955)** and damaged starch **(Pretson and Tipples, 1978)**. Other factors including cooking method, temperature of drying and milling conditions affecting the particle size also affected the water absorption and rehydration rate **(Staal *et al.*, 1990)**. The rate of water uptake increased with decreasing particle size of dried potato flakes. Total water uptake was greater for flakes than granules.

According to **Lisinska and Leszczynski (1989)** coarser particles absorbed less water than finer. It is highly essential in processing of potato powder that there should be minimum number of ruptured cells as it affects the texture of the rehydrated product **(Purves and Sniverly, 1975)**.

Hadziyev and Steele (1979) suggested that the cell rupture could be reduced with the help of add-back process including peeling, slicing, pre-cooking, mashing, mixing, conditioning, remixing, air sift drying or fluid bed drying, cooking and sieving, **Hodge and Osman (1976)** reported that cell fractures occurred when the granules are crushed.

Cracking or fracturing is also due to drying at elevated temperatures **(Whistler *et al.*, 1958)** or during milling due to mechanical damage **(Matz, 1960)**. These cracks have pronounced effect on pasting characteristics, enzyme digestion and viscosity because surface area of starch granules is increased followed by increased chemical reactivity.

2.7 Nutritional value of potato flour and other dehydrated products

2.7.1 Moisture

Willard and Hix (1987) reported moisture content in potato flour in the range of 6.81 to 7.50 per cent with an average of 7.39 per cent. **Yanez *et al.* (1981)** reported the moisture content of potato flour as 7.2 per cent and that of wheat flour as 12 per cent, whereas **Chandrashekara and Shurpalekar (1983)** found a moisture content of 9.7 per cent in potato flour. **Vaidehi and Sunanda (1982)** reported the moisture content of potato flour as 8 per cent and that of potato sticks, potato gratings and potato sooji as 5.9 per cent, 9.0 per cent and 8-9 per cent respectively. The sun-dried potato flour and chips were sufficiently dry and contained low moisture content (7.6 to 8.6 per cent in flour and 5.1 to 6.7 per cent in chips) **(Rai, 1990)**. **Nanda and Khanna, 1988** also reported a moisture content of 8.91 per cent in potato flour. **Petelle *et al.* (1995)** reported the moisture content of fat free potato chips as 7 per cent.

The normally dried potato flakes have a moisture content of 4.69 per cent and flakes processed from good raw material were stable during storage **(Sapers *et al., 1974*)**.

2.7.2 Protein

Chandrashekara and Shurpalekar (1983) reported the protein content of potato flour as 8.1 per cent and this was very high than the protein content (1.2%) of sweet potato flour as described by **Hamed *et al*, 1973; Akubor (1997)**. **Yanez *et al* (1981)** reported the protein content of potato flour as 6.7 per cent on fresh weight basis as compared to 9.3 per cent of wheat flour. **Treadway *et al.* (1950)** studied the protein content of potato flours produced from potatoes cultivated in various regions/countries on moisture free basis. They reported that protein content ranged from 9.44 to 11.29 per cent with an average of 10.38 per cent. **Willard (1967)** found a range of 6.69 to 8.13 per cent on fresh weight basis, while, **Nanda and Khanna (1988)** reported protein content as 7.50 per cent on dry weight basis in potato flour. According to **Gahlawat and Sehgal (1998)** the protein content of potato flour ranges from 6-12 per cent i.e. similar to that present in common cereals.

Dehydration had little effect on the nitrogen content of granules, slices and dices, but considerably reduced in flakes. The overall retention values for total nitrogen were 83 per cent (granules), 85 per cent (slices), 86 per cent (dices) and 70 per cent flakes **(Weaver *et al.*, 1983)**.

2.7.3 Fat

Yanez *et al.* (1981) studied the fat content of potato flour and wheat flour and reported that potato flour contained 0.3 per cent fat as compared to 1.2 per cent in wheat flour on fresh weight basis. **Chandrashekara and Shurpalekar (1983)** reported fat content of potato flour as 0.8 per cent, as compared to 1.3 per cent of wheat flour on dry weight basis. **Willard (1967)** reported fat content in the range of 0.45 to 1.39 per cent on fresh weight basis. **Gahlawat and Sehgal (1998)** reported the fat content of potato flour as 1 g/100 g on dry weight basis. **Akubor (1997)** also reported the similar fat content of sweet potato flour as 0.30 per cent.

2.7.4 Total ash

Willard (1967) reported 3.32 per cent ash in potato flour on fresh weight basis. **Treadway *et al.* (1950)** studied ash content of potato flour from potatoes grown in various areas and found a range of 2.97 to 5.95 per cent with an average of 4.50 per cent on dry weight basis. According to **Chandrashekara and Shurpalekar (1983)**, the total ash content of potato flour was 2.5 per cent on dry weight basis as compared to 0.7 per cent of wheat flour. The values of potato flour were also in agreement with the sweet potato flour, that is, 2.5 per cent **(Akubor, 1997)**. **Yanez *et al.* (1981)** studied the ash content of wheat flour and potato flour and observed 2.2 and 0.6 per cent ash, respectively on fresh weight basis. The ash content of potato flour was reported as 5.83 g/100 g on dry matter basis by **Gahlawat and Sehgal (1998)** and was recorded as 3.82 g/100 g on dry weight basis by **Nanda and Khanna (1988)**.

2.7.5 Carbohydrates

Treadway *et al.* (1950) studied the assimilable carbohydrate in potato powder and found it in the range of 71.0 to 84.0 per cent with an average of 78.0 per cent, whereas, **Chandrashekara and Shurpalekar (1983)** found the carbohydrate content of potato flour as 87.3 per cent and this was in agreement with the values reported by **Akubor (1997)** for the sweet potato flour. **Chandrashekara and Shurpalekar (1983)** further reported 2.2 per cent reducing sugars and 2.3 per cent non reducing sugars in potato flour on dry weight basis. **Nanda and Khanna (1988)** reported carbohydrate content as 80.88 g/100 g on dry weight basis in potato flour.

2.7.6 Total starch

Chandrashekara and Shurpalekar (1983) reported starch content of potato flour as 81.2 per cent on dry weight basis. A starch content of 77.65 per cent was recorded on dry weight basis by **Nanda and Khanna (1988)**.

2.7.7 Minerals

According to **Roy Chaudhuri *et al.*, (1963a)**, there was some loss of minerals during processing, which was due to leaching during blanching and sulphite dipping.

Potato flour was found to contain 3.95 mg of iron and 30.16 mg of calcium per 100 g on dry weight basis. The total phosphorus content of potato flour on dry weight basis was 177.4 mg/100 g **(Nanda and Khanna, 1988)**. The *in vitro* availability of calcium and iron of potato flour, used in preparation of different products was recorded as 38.99 per cent and 12.06 per cent, respectively **(Gahlawat and Sehgal,1998)**.

2.7.8 Vitamins

Vencken and Ebbenhorst (1990) studied the effects of processing on the vitamin content of potato flakes. Total ascorbic acid loss during processing was 40 per cent, mainly during peeling and drying. Thiamine content decreased 35 per cent and pyridoxine content decreased 30 per cent during processing. No significant variation in riboflavin content occurred during processing.

Ascorbic acid is the most difficult of the vitamins to preserve during dehydration of foods. Losses of vitamin C were observed by **Roy Chaundhuri *et al.* (1963a)** during preparation of potato flour and was about 50 per cent of that present in raw tubers. **Burton (1966)** also reported that there was a loss in both ascorbic acid content and vitamin B_1 (thiamine) during preparation of potato flour. **Jadhav *et al.* (1975)** reported losses in vitamin C content during the production of dehydrated mashed potatoes. **Nanda and Khanna (1988)** reported vitamin C content in potato flour as 5.67 mg/100 g. Most of it was destroyed on boiling and then sun drying of the tubers.

Overall losses of vitamins in the finished french fries were 44 per cent ascorbic acid, 44 per cent thiamine, 39 per cent riboflavin and 24 per cent niacin **(Gorun, 1978). Pelletier *et al.* (1977)** reported about 30-85 per cent losses in ascorbic acid in the preparation of chips. Retention of thiamine was relatively high (64 per cent) during the production of potato flakes **(Augustin *et al.*, 1979). Steele *et al.* (1976)** reported about 74 per cent losses in ascorbic acid in granules.

According to **Marwaha (1997)** ascorbic acid and folic acid suffer large losses during cooking and processing as a result of leaching, heat destruction and oxidation. **Roy Chaudhuri *et al.* (1963b)** reported that vitamin C contents of processed potatoes were lower than the raw potatoes. Losses of vitamin C due to different methods of processing were 20-28 per cent in water cooked, 50-56 per cent in baked and 50-59 per cent in deep fat fried. **Burton (1989)** compiled the average losses of vitamin C during various methods of processing which were 20 per cent in unpeeled boiled, 25 per cent in peeled-boiled, 30 per cent in french fries, 30-35 per cent in chips and 70 per cent in reconstituted instant powder and flakes.

2.7.9 *In vitro* protein digestibility

Gahlawat and Sehgal (1998) reported the *in vitro* protein digestibility (IVPD) of potato flour as 73.27 ±2.92 per cent and was higher than that of raw potatoes.

2.7.10 Dietary fiber

According to **Southgate and White (1981)** the total dietary fiber values in potato flour ranged from 6.4 g/100 g to 26.3 g/100 g on dry weight basis with a mean value of 17.6 g/100 g. **Theander and Aman (1981)** reported the total dietary fiber value as 6.0 g/100 g, water soluble fiber as 1.4 g/100 g and water insoluble fiber as 4.6 g/100g in potato flour on dry weight basis. **Hellendoorn *et al.* (1975)** recorded the water soluble fiber, water insoluble fiber and total dietary fiber values of potato flour as 2.6 g/100 g, 7.2 g/100 g and 9.8 g/100 g on dry weight basis, respectively.

2.8 Microbial load of potato flour

Burton (1945) found mold growth at a moisture content of 13.50-15.00 per cent and temperature between 25-37°C. He further reported that storage at 20°C caused mould growth when the moisture content of potato flour was 15.0 per cent.

2.9 Storage of potato flour

Burton (1945) reported that unless the conditions for storage were very carefully monitored, potato flour could not be kept for indefinite period and its quality would certainly deteriorate. **Tomkins *et al.* (1944)** and **Burton (1945)** studied the effect of high storage temperature on potato flour and found that storage at high temperatures led to darkening in colour and loss of the ability to absorb water, particularly in high moisture content flour. They further reported that browning developed in mashed potato powder at high storage temperature and this was correlated with the high content of reducing sugars.

The discolouration of potato powder during storage is due to non-enzymatic browning caused by Maillard reaction and ascorbic acid browning **(McBean *et al.*, 1971)**. The presence of oxygen accelerates the above reaction and causes browning of potato flour, stored in polythene pouches **(George and Mahadeviah, 1989)**.

One year storage studies of potato flour conducted by **Sagar and Roy (1997)** revealed that the potato powder packed in 400 gauge polyethylene bags gained less moisture as compared to 200 gauge polyethylene bags, both at room temperature and cool store. Gain in moisture occurred in potato powder with increase in storage time (from 3 to 12 months of storage) and this was recorded as 7.52 per cent from an initial value of 7.39 per cent at room temperature and 7.71 per cent from an initial value of 6.93 per cent at cool storage. The potato powder stored at low temperature was found better in colour and flavour. Whereas, in the case of potato powder stored at room temperature, the non enzymatic browning was more as compared to cool storage and increased with storage time, which is directly related to the colour of the product. From the study, the workers concluded that polyethylene bags (400 gauge) were found to be suitable for storage of potato powder for 6 months at room temperature and for 9 months at low temperature.

According to **Vaidehi and Sunanda (1982)**, there occurred an increase in the moisture content of dehydrated products of potatoes such as sticks, gratings, suji and flour, over a period of six months. The moisture content of potato flour stored in polythene pouches, after six months of storage was recorded as 9.6 per cent, as compared to its initial value of 8.0 per cent. They further reported that dehydrated potato products could be safely stored for six months without any fungal or insect infestation and also there occurred no change in colour, odour and flavour. **Burton (1949)** and **Sapers *et al.*, (1972)** reported that shelf life of dehydrated instant mashed potatoes is limited by oxidative reactions which result in the development of hay-like off-flavours during storage, particularly if the moisture content was low. The off flavour was due to oxidation of potato fat. **Burton (1949)** suggested that in cool climate, the off flavour development could be checked if the moisture content of potato powder was about 10 per cent. He further reported that in hot climate, potato powder could be kept for longer period in an atmosphere of nitrogen.

During 12 months of storage at –18°C, there were no changes in terms of contents of dry matter, starch, organic acids, or mono and disaccharides in cubes of fast frozen potato puree. Vitamin C losses after 12 months of storage was 54.3 per cent in the product **(Shagina**

and Lugovaya, 1993). Wang *et al.* (1992) studied the ascorbic acid losses and reported the losses as 82 per cent for drum dried potatoes and potato flakes stored for 4.3 months at 25°C and 96 per cent losses for reconstituted mashed potatoes. **Vencken and Ebbenhorst (1990)** studied the effect of storage on the vitamin content of potato flakes, stored at –20°C or + 20°C for upto 12 months. They reported that ascorbic acid content of the flaked product decreased approximately 30 per cent during the first 6 months of storage, irrespective of temperature. However, little change in thiamine, riboflavin or pyridoxine content of the flaked product was observed, irrespective of duration and temperature of storage. According to **Roy Chaudhuri *et al.* (1963a)** vitamin C content was lost during 6 months of storage of potato flour in sealed polythene bags at 37°C. They also observed about 90 per cent loss in thiamine during the preparation of potato flour.

Studies conducted by **Anand *et al.*, (1982)** indicate that chips made from potato tubers can even be stored upto one year, without affecting the colour and taste.

Srivastava *et al.* (1973) also quoted that the potato slices dried in sun could be stored in air tight containers or sealed polyethylene bags for a period of 6 months. Slices of peeled potato tubers soaked in dilute solution of oxidizing agents as sodium hydroxide or acetic acid for half an hour and dried in hot air oven, could be kept for months without spoiling and needs no extra equipment for safe storage **(Food Digest, 1998). Nanda and Khanna (1988)** reported that the potato flour stored in air tight containers at room temperature for 3 weeks (21 days) did not develop any adverse colour, flavour or taste and thus can be incorporated into various recipes both in home and industry and make up the cereal deficit in our country.

Roy Chaudhuri *et al.* (1963a) reported that the addition of hydrogenated groundnut oil at a level of 5 per cent improved the shelf life of the potato flour at 37°C. The quality of potato powder remained unchanged for one year at —18°C. **Danowska and Barowski (1994)** described that the addition of dried skim milk or faba bean flour to the dried potatoes showed consumption quality even after 12 months of storage. **Stephenson *et al.* (1958)** found that small quantities (1-5 ppm) of antioxidants like BHA and BHT could be added to potato flour to prevent oxidative rancidity.

Hamed *et al.* (1973) observed that the moisture content of the sweet potato flour samples increased from 6.5 per cent to 8.8 per cent, when stored at room temperature for about 2 months (73 days).

ElAdawy Nassef and Attia (1995) reported that potato flour obtained from potato tubers, when combined in 0-15 per cent mixtures with wheat flour and stored for six months contained twice the lysine content of wheat flour, but protein levels fell as potato flour levels in the mixture were increased.

According to **Beristain *et al.* (1990)** the whole potato flour (prepared from unpeeled potatoes) packed in polyethylene bags and stored for 10 months at room temperature showed no brown colour formation or mould growth during storage. The whole flour had moisture content of 7.00 per cent, protein 6.70 per cent, fat 0.46 per cent, ash 2.29 per cent and carbohydrate 80.58 per cent.

Wills and Silalahi (1990) estimated the loss of vitamin C in potato crisps stored at 2, 20, 30 and 50°C for 12 weeks (3 months) and showed that crisps at 2°C showed little loss of vitamin C but the rate of loss increased exponentially as the temperature increased. They suggested that 20°C was the maximum temperature for retention of vitamin C during storage.

Choi and Koh (1991) reported that the total lipid content of the potato flour (non microwaved) stored at 25±1°C for upto 12 months, decreased with increasing storage time. The main fatty acids in the flour were recorded as linoleic acid (30.92 per cent), palmitic acid (29.3 per cent), linolenic acid (8.90per cent) and stearic acid (8.23 per cent) of the total fatty acids and as the storage time increased, saturated fatty acids increased and unsaturated fatty acids decreased.

Kulkarni *et al.* (1993) reported that storage had no significant effect upon composition of the potato flour developed from two commercially important cultivars.

According to **Sagar and Roy (1997)**, the optimum relative humidity for storage of potato powder was found to be 60 per cent when the initial moisture of the potato powder was 4.18 per cent. The potato powder retained its quality with respect to colour, flavour, texture and overall acceptability upto 60 per cent relative humidity (RH). When the product was exposed to 74 per cent relative humidity, the equilibrium moisture content (EMC) value of the product increased to 11.70 per cent and the product became lumpy and hence unacceptable. Mould growth was observed at 15.39 per cent EMC after 30 days of storage.

2.10 Product formulation using potato flour

Potato flour is the oldest commercially processed potato product and its incorporation in various products is desirable **(Gahlawat and Sehgal, 1998)**. According to **Vaidehi (1987, 1988)** different products can be prepared by incorporating potato flour with other flours using different methods of cooking such as baking, roasting, steaming, boiling and deep fat frying etc. **Nanda and Khanna (1988)** observed the organoleptic acceptability of potato flour incorporated food products such as dalia, tomato soup, vegetable stew, phirni, khichri, biscuit, sev, panjiri, parathas and upma. They reported that all the recipes were rated as very good and there occurred no deterioration in the appearance, colour, texture or taste of the product due to addition of potato flour.

2.10.1 Baked products

Potato flour is commercially important in baking industries **(Singh and Verma, 1979)**. Potato flour is used by the baking industry, especially in the baking of bread to retain its freshness, impart a distinctive pleasing flavour, improve the toasting quality and crust colour. Potato flour can be mixed with wheat flour upto 6 per cent for bread making **(Rao, 1998; Marwaha and Sandhu, 1999)**.

Fresher and tastier bread was reported to have been obtained by addition of 2 to 3 per cent potato flour. The crust colour, loaf volume, added freshness in flavour and better toasting qualities were found to be obtainable in baked products with the use of potato flour **(Nelson, 1978)**. Bread containing potato flour retains more water and kept for a longer period than wheat bread. This may represent an important advantage over wheat bread which has a shorter shelf life due to moisture loss. **Yanez *et al.* (1981)** suggested that the substitution of wheat flour by potato flour would not exceed 8 per cent.

Treadway (1949) reported that constituents of potatoes were recognized as outstanding among bread ingredients for their ability to stimulate growth of yeast cells and activate fermentation of sugars.

Willard (1967) reported that use of potato flour was not only confined to bread alone but could be used advantageously in crackers, pastries, yeast raised dough nuts, cakes and cake mixes. Addition of potato flour (12 to 20 per cent) in crackers offered a number of advantages like flavour intensification and more complete fermentation.

Stute (1995) suggested the application of potato granules in bread and various other bakery products. Its suitability for use in bakery products was attributed to high bulk density, low bulk volume, good mixability with other bulk foods and low free starch content. Use of potato granules in wheat and mixed wheat/rye bread, cakes and biscuits at 1-10 per cent level improved freshness retention and consistency characteristics. **Chandrashekara and Shurpalekar (1984b)** also reported the use of potato flour in biscuits. They prepared biscuits using varying amounts of potato flour and cassava flour with wheat flour and reported that 40 per cent wheat flour could be replaced for making biscuits of improved acceptability using a 60:20:20 blend of wheat flour, cassava flour and potato flour respectively. Use of potato flour helped in masking the undesirable effects of cassava flour such as fragility, mouth feel and colour. In a study by **Beristain *et al* (1990)** biscuits made from whole potato flour were also found to be acceptable. **Kulkarni *et al.* (1996)** also prepared potato cake with potato flour. Best results with the potato cake were obtained with one part potato flour to three parts powdered milk, the result being rated as superior to a commercial cake.

Biscuits of improved taste and texture were made when half of the wheat flour was replaced by potato flour. However, biscuits prepared from pure potato flour gave a typical taste and flavour and were not found to be acceptable **(Marwaha and Sandhu, 1999)**.

2.10.2 Snack foods

Potato flour, a highly versatile raw material is used as a base ingredient in several commercially produced snack foods. **Marwaha and Sandhu (1999)** reported that potato flour and potato granules can be used for preparing tikkis in the fast food outlets and extruded products like papad as a cottage industry. Potato flour also finds its use in the preparation of idli, alu bhujiya etc.

Kulkarni *et al.* (1993) reported the use of potato flour in mash and rasgulla. Mash made from the flour was judged acceptable and rasgulla containing 33 per cent potato flour was more acceptable than the commercial product. In another study by **Kulkarni *et al.* (1996)**, they used potato flour to prepare mash, gulab jamuns and paratha 3 traditional Mauritian foods. Mash samples were superior to a commercial instant potato mash. Gulab jamuns with milk and potato flour in ratios of 3:1 and 5:1 were superior to commercial samples and parathas made with 40 per cent potato flour were more acceptable than those made with wheat flour alone.

2.10.3 Thickener

Another use of potato flour is a combination thickener – flavouring agent in products such as dehydrated soups, gravies, sauces and baby foods **(Marwaha and Sandhu, 1999)**. A sterilized potato flour has found use in baby foods where it acts as a healthful and flavoured thickener **(Willard and Hix, 1987)**. Custard powder was prepared from combinations of potato starch (90 per cent) and potato flour (10 per cent). Addition of 10 per cent potato flour in the custard powder mix, apart from economizing the cost of production, also improved the taste and texture of custard pudding. 2 per cent potato flour-starch combination (1:1) proved to be good thickening agents and were effective in bringing the desired consistency in tomato and chicken soups when compared with commercially available corn flour **(Marwaha and Sandhu, 1999)**. **Musette and Bussiere (1977)** obtained a powder by drum drying at a temperature sufficeint to gelatinize the starch. This powder on rehydration was used as an additive for jams, marmalades, sauces, tomato purees, fruit juices, drinks and confectionary.

2.11 Nutritional value of potato flour incorporated food products

Burg and Fraile (1995) studied the effects of domestic cooking on vitamin C content of potato dish (potato cubes). They reported that vitamin C destruction during cooking was mainly due to enzymic destruction and enzyme thermal deactivation reactions.

According to **Yanez *et al.* (1981)** potato flour incorporated bread showed a trend to a higher water content with higher levels of potato flour from 33.3 per cent for the control (0 per cent) potato flour) to 38.6 per cent for the 10 per cent potato flour level. The protein content decreased with the incorporation of potato flour, the values ranging from 7.2 per cent for 0 per cent potato flour to 6.3 per cent for 10 per cent potato flour incorporated bread. The bread showed the same ash content (1.7 per cent) in 0 to 10 per cent potato flour incorporated bread. Fat content varied from 0.6 per cent for control bread while values ranging between 0.4 and 0.5 per cent for potato flour incorporated bread from 2 to 10 per cent. The substitution of wheat flour by potato flour did not modify the PER upto 8 per cent level, however, bread containing 10 per cent potato flour showed a significant decrease in PER. Beyond 8 per cent level, the biological quality of the protein is significantly decreased. Thus, the addition of potato flour at the levels of 2,4,6 and 8 per cent did not impair the nutritive value of bread.

Bascunan (1979) studied the effect of fortification of wheat flour with potato flour in bread preparation using 2,4,8 and 10 per cent potato flour respectively. He observed increased water absorption with increase in level of potato flour, however, protein content showed a decrease with increased amounts of potato flour. Ash content did not show a marked change consumer acceptability trials indicated that bread prepared with 8 per cent potato flour was quite satisfactory.

Li and Li (1979) observed that addition of 10-12 per cent potato flour could be added to wheat flour without impairing the quality of bread.

Materials and Methods

3. MATERIALS AND METHODS

3.1 Selection of sample

For preparing potato flour, three commercially released varieties of potato (*Solanum tuberosum*) namely Kufri Sutlej (K.Sutlej), Kufri Ashoka (K.Ashoka) and OP-1 were selected. Fully matured potatoes of uniform shape and size of each variety were procured from the Horticultural Research Centre, Patharchatta, G.B. Pant University of Agriculture and Technology, Pantnagar, at the time of harvest (March, 1999).

3.2 Preparation of potato flour

The flow diagram for the production of potato flour is given in Figure 3.1, which involves the following process:

3.2.1 Sorting and washing

Uniform sized potatoes of each variety having no sign of infection and infestation were thoroughly washed in running water to remove any soil, dirt and dust.

3.2.2 Boiling

For the preparation of potato flour, potatoes of each variety were pressure cooked. The boiled tubers of each variety were also observed for the following characteristics **(Burton, 1989)**:

1. Colour (visual) : Creamy, white, off- white or yellow
2. Disintegration (visual) : Ranging from none to complete
3. Consistency (touch) : Ranging from firm to soft, and also uneven

Potatoes

↓

Sorting and washing

↓

Boiling (pressure cooking for 15-20 minutes 10 l.b. psi)

↓

Peeling

↓

Grating

↓

Drying (55^0C for 24 hours)

↓

Grinding

↓

Powdering

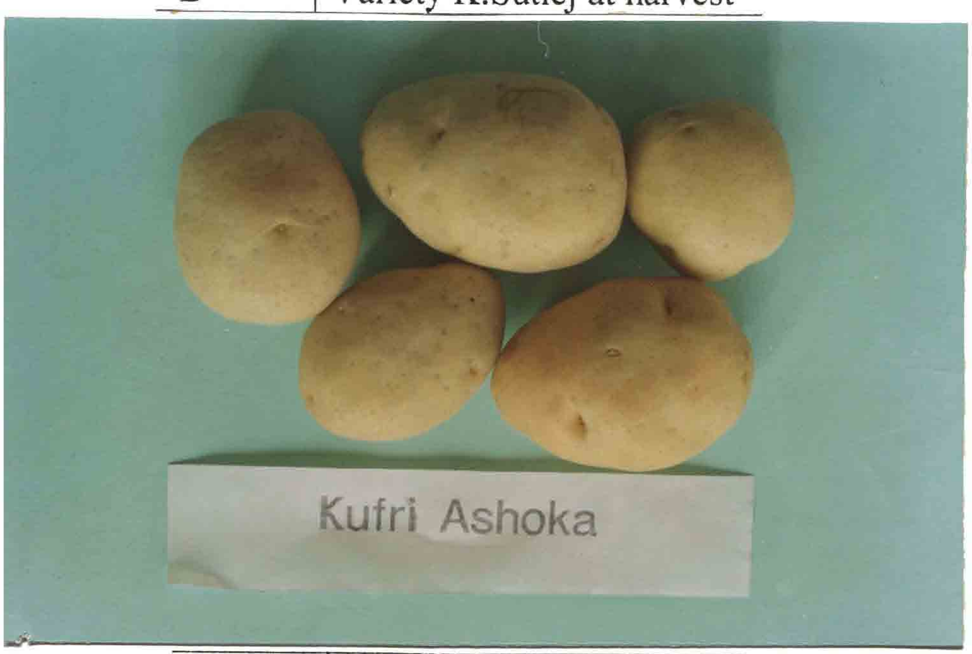
↓

Packing

Figure 3.1 : Flow diagram for the production of potato flour

A | Variety OP-1 at harvest

B | Variety K.Sutlej at harvest



C | Variety K.Ashoka at harvest

4. Mealiness (taste) : Ranging from not mealy to very mealy
5. Dryness (visual) : Ranging from moist to dry
6. Structure (touch) : Ranging from fine to coarse

Potato varieties were also categorized into different texture categories as floury, close, waxy soapy according to the characteristics given by **Burton (1989)**.

3.2.3 Peeling and grating

Boiled potatoes of each variety were peeled off and peeling losses measured. Peeled potatoes were then grated using stainless steel grater.

3.2.4 Drying and grinding

The grated samples of potatoes were spread on the perforated polyethylene sheet lined trays in a uniform single layer and kept in tray drier at 55^0C for 24 hours. After complete drying, dried samples of potatoes were reduced by grinding in an electric grinder and finally powdered in a Brabender unit (Duisburg Type 279001). The potato flours so obtained, from each variety were packed in double polyethylene bags and sealed in air tight plastic containers until used.

3.3 Storage of potato flour

The packed potato flour samples of all the three varieties sealed in air tight containers were stored at refrigerated (4-5^0C) temperature and at room temperature (12.25-37.1^0C) for a period of six months.

The samples were drawn at 0, 3 and 6 month storage period for their evaluation.

The samples to be stored at refrigerated temperature were kept in refrigerator and those to be stored at room temperature were kept in room itself, away from sunlight. The range and mean of maximum and minimum daily temperature recorded during three months and six months of storage is given in Appendix I.

3.4 Analytical parameters

Potato flour samples of each variety, freshly- prepared as well as stored under different conditions and durations were analyzed for various parameters. Analytical procedures were performed on

(i) Freshly prepared potato flour samples i.e. control or zero time storage

(ii) Potato flour samples stored for three months, both under room and refrigerated temperature.

(iii) Potato flour samples stored for six months, both at room and refrigerated temperature.

The different parameters determined for all the flour samples are following :

3.4.1 Physico-chemical characteristics

1. Colour
2. Water absorption capacity

3. Moisture sorption isotherm

4. Particle size index

3.4.2 Nutritional value

1. Moisture

2. Protein

3. Total ash

4. Dietary fiber

5. Total starch

6. *In vitro* protein digestibility

7. Minerals

    Calcium

    Phosphorus

    Iron

8. Ascorbic acid

3.4.3 Microbial load

1. Total bacterial count

2. Coliform count

3.4.1. Physico-chemical characteristics

3.4.1.1 Colour

Colour of the potato flour samples of each variety was determined using **Munsell soil colour chart (1954)**. The figures of hues and values were noted.

3.4.1.2 Water absorption capacity

Water absorption capacity of potato flour samples of each variety was estimated according to the method given by **Smith and Circle (1972)** for soyflour. Exactly 5 g of potato flour was mixed well with 30 ml distilled water in a centrifuge tube using a glass rod. After five minutes, the contents were centrifuged at 2000 rpm for five minutes. The supernatant was measured using a graduated cylinder.

Volume of water absorbed = 30 – supernatant

$$\text{Water absorption (\%)} = \frac{\text{Volume of water absorbed}}{\text{Weight of sample}} \times 100$$

3.4.1.3 Moisture sorption isotherm

Moisture sorption isotherm of potato flour samples was determined using Wink's weight equilibrium method given by **Ranganna (1994)**.

The procedure involved samples of the product under test to be brought to actual weight equilibrium when exposed to different relative humidities. Saturated salt solutions of varying relative humidity (R.H.) at room temperature were used.

The Equilibrium Relative Humidity (ERH) values for a number of salts used are given in Table 3.1.

Table 3.1 : Equilibrium Relative Humidities for saturated salt solutions

Sl. No.	**Chemical**	**Formula**	**Relative humidity in percentage at 30°C (86°F) temperature**
1.	Ammonium phosphate	$NH_4H_2PO_4$	92.0
2.	Potassium chromate	K_2CrO_4	86.3
3.	Ammonium sulphate	$(NH_4)_2SO_4$	79.6
4.	Sodium acetate	$NaC_2H_2O_2$	71.4
5.	Sodium nitrite	$NaNO_2$	63.3
6.	Magnesium nitrate	$Mg(NO_3)_2$	51.4
7.	Potassium carbonate	K_2CO_3	43.5
8.	Magnesium chloride	$MgCl_3$	32.4
9.	Potassium acetate	$KC_2H_3O_2$	22.0
10.	Lithium chloride	LiCl	11.2

Approximately, 100 ml of saturated salt solution was poured into each desiccator. Salt in excess was added to ensure a saturated condition of the solution.

Exactly 5 g lots of the flour were weighed and spreaded uniformly on petri dishes. The initial moisture content of the flour was determined. The dishes were then exposed to different relative humidities ranging from 0 to 92 per cent inside desiccators containing saturated salt solutions at room temperature. 0 % RH was maintained in a desiccator containing fused calcium chloride. Gain or loss in weight of the samples at the end of 1, 2, 3 , 4, 5 and 6 hours were determined and, therefore, at intervals of 24 hours upto 360 hours (15 days), with a view to determine the moisture equilibrium of the flour at 30°C temperature. Meanwhile any adverse changes in the flour were observed such as caking, discolouration, mould growth etc.

Weight of the flour samples were recorded, when there was no further loss or gain. The equilibrium moisture content was calculated at each relative humidity using the following expression :

$$\text{Equilibrium moisture content (\%)} = \frac{S - X}{S} \times 100$$

Where,

S= Weight of the sample after equilibration

X = Dry matter content in the sample taken for determination of ERH

3.4.1.4 Particle size index

The particle size index of the potato flour samples was determined according to the method of **Bedolla and Rooney (1984)** by sieving 100 g flour samples on a series of no. 60 (250 μm), 70 (212 μm) and 80 (180 μm) mesh standard sieves. The sieves were shaken for 15 minutes in a Ro - tap type sieve shaker. Weight of the samples over 60, 70 and 80 mesh sieves were recorded and PSI was calculated as :

PSI = [(0.1) (per cent on 60 mesh) + (0.4) (per cent on 70 mesh) + (0.7) (per cent on 80 mesh) + (1.0) (per cent through 80 mesh)].

3.4.2 Nutritional value

3.4.2.1 Moisture

Moisture content of the samples was determined according to the procedure given by **AOAC (1975)**.

3.4.2.2 Protein

The protein content of the flour was determined by Kjeldahl procedure, as described in **AOAC (1975)**.

Two grams of sample was digested with five grams of digestion mixture (potassium sulphate and copper sulphate in 96 : 4 ratio) and 20 ml of concentrated sulphuric acid in a Kjeldahl flask until the contents were bluish green in colour. The volume of digested sample was made upto 100 ml with distilled water in a volumetric flask. An aliquot of 10 ml was distilled with 40 per cent (10 ml) sodium hydroxide solution and liberated ammonia was collected in 20 ml of 4 per cent boric acid containing two to three drops of mixed indicator (0.1 per cent methyl red and 0.1 per cent bromocresol green in the ratio of 1 : 5). The entrapped ammonia was titrated against 0.1N hydrochloric acid till pink colour appeared. Blank determination was done by taking sucrose in place of sample. The nitrogen content in the samples was calculated by the following expression :

$$\text{Per cent nitrogen} = \frac{14 \times \text{N of HCl} \times (\text{Sample titre} - \text{blank titre}) \times \text{dilution factor} \times 100}{\text{Weight of sample} \times 1000}$$

Per cent protein = per cent nitrogen × 6.25

3.4.2.3 Dietary fiber

Dietary fiber was determined by the method described by **Asp and Johansson (1981)**.

Eight hundred milligrams (0.8 g) of sample was taken in a conical flask and 50 ml distilled water was added to it. It was then boiled at 100^{0}C for 15 minutes to gelatinize starch molecules. Fifty ml of 0.2N hydrochloric acid followed by 300 mg (0.3 g) pepsin, was added to the flask (pH – 1-2). Incubation was done for 18 hours at 40^{0}C and then neutralized with sodium hydroxide to bring pH 7.0. Exactly, 50 ml of 0.1 M sodium phosphate buffer was added to maintain pH 6.8. Then 3 ml. of Dimethyl Sulfoxide (DMSO) was added followed by 300 mg (0.3 g) pancreatin. Incubation was done with agitation for one hour at 40^{0}C. Acidification to pH 4-5 was done with hydrochloric acid and then centrifuged at 3000 rpm for 30 minutes. Filtration was done in a Gooch crucible and sediment washed with water three times (3 × 50 ml water).

The residue and supernatant so obtained were estimated for water insoluble fiber (WIF) and water soluble fiber (WSF), respectively as per the following procedure:

Residue	Supernatant and first water wash
• Washed sediment with 2 × 50 ml acetone • Dried at 105^{0}C overnight	• Evaporated to 150 ml • Aliquot precipitated with 4 volume of 95% ethyl alcohol centrifuged at 3000 rpm for 30 minutes.
• Crucible weighed to determine water insoluble fiber content of the sample	• Washed sediment with 3 × 50 ml of 80% ethyl alcohol and 2 × 50 ml acetone • Oven dried at 50-60^{0}C for one hour • Crucible weighed to determine water soluble fiber content of the sample

Total dietary fiber in the potato flour samples was calculated as following:

Total dietary fiber = Water insoluble fiber + water soluble fiber

3.4.2.4 Total starch

Total starch content of the flour was estimated by colorimetric method as described by **Ranganna (1994)**.

3.4.2.4.1 Preparation of sample

This involves the extraction of sugars from sample, preparing it for starch analysis. Two hundred milligrams of potato flour sample was taken into a 50 ml centrifuge tube. To the sample, few drops of 80 per cent ethyl alcohol and 5 ml of water was added and stirred thoroughly, to wet the flour and prevent clumping. Twenty five ml of hot 80 per cent ethyl alcohol was added to the centrifuge tube, mixed and stirred vigorously, and centrifuged at 2500 rpm. for five minutes, after five minutes of standing. The supernatant was then decanted and discarded off. Again, 25 ml of hot 80 per cent ethyl alcohol was added, stirred and centrifuged as before. The alcoholic solution (supernatant) was discarded. This washing, centrifuging and decanting was repeated twice more, for a total of four washings.

After the final extraction, 5 ml of water was added to the residue and stirred. It was then cooled in an ice water-bath, and while stirring, 6.5 ml of 52 per cent perchloric acid was added. The solution was stirred for five minutes and occasionally thereafter, for fifteen minutes. Twenty ml of water was added and centrifuged at 2500 rpm for five minutes. The supernatant that is the aqueous soluble starch solution was poured off into a 100 ml volumetric flask. Five ml of water was added to the residue in the centrifuge tube, cooled in ice water bath, and added slowly with stirring, 6.5 ml of 52 per cent perchloric acid. The solution was solublized as before for thirty minutes at 0^0C with occasional stirring and washed the contents of the tube into a 100 ml volumetric flask containing the first extract. The volume was made up to 100 ml with water and filtered. The first few ml (5 ml) of the filtrate was discarded.

3.4.2.4.2 Colour development

An aliquot of 5 ml of filtrate was diluted to 500 ml with water (to contain 5-20 μg of starch per ml). To 5 ml of this diluted solution, 10 ml of fresh anthrone reagent was added, mixed thoroughly and heated for 7.5 minutes in a boiling water bath. It was cooled to room temperature. The green colour developed was measured within thirty minutes, at 630 nm in a colorimeter (Systronics-Balanced cell colorimeter) using red filter.

3.4.2.4.3 Preparation of standard curve

A series of 0.5 ml, 1.0 ml, 1.5 ml and 2.0 ml of dextrose standard solution (1 mg/ml) in 100 ml volumetric flask was taken and volume made up with water. 5 ml of each solution (equivalent to 25, 50, 75 and 100 μg of dextrose) and blank was taken and colour developed as in samples. The green colour so developed was measured at 630 nm in colorimeter. The concentration of standard

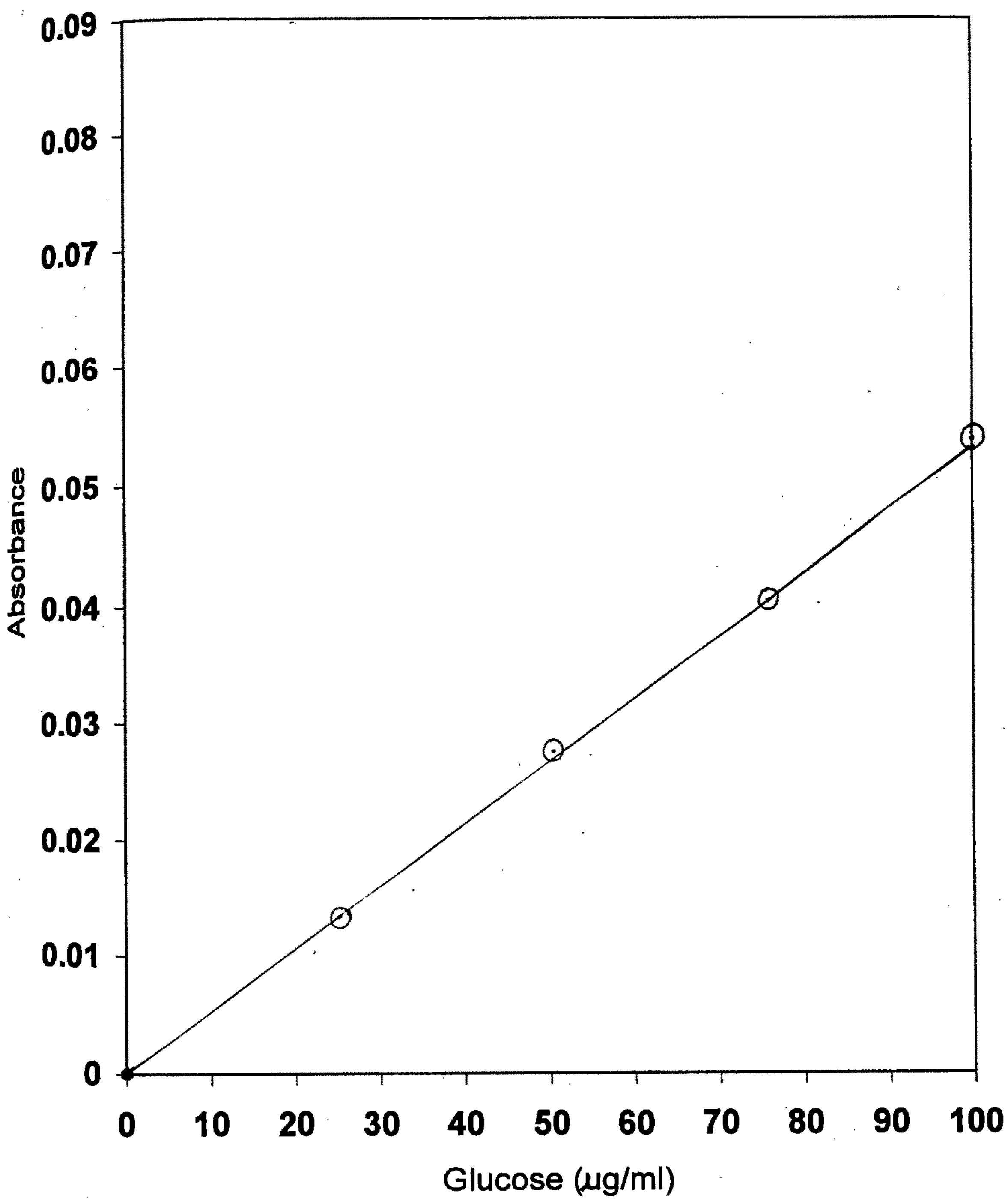


Figure 3.2: Glucose standard curve for starch estimation

dextrose solution was plotted against absorbance to get the standard curve as shown in Figure 3.2. The glucose content obtained was multiplied with 0.9 to get starch content of samples.

3.4.2.5 *In vitro* protein digestibility

The *in vitro* protein digestibility of the potato flour samples was determined by a modified procedure of **Akeson and Stahmann (1964)**.

Pepsin followed by pancreatin digest were prepared by incubating one gram of sample with 12.5 mg (0.0125 g) pepsin in 15 ml of 0.1N hydrochloric acid at 37^{0}C for 3 hours. After neutralization with 1.5 ml of 0.2 N sodium hydroxide and addition of 4 mg (0.004 g) pancreatin in 7.5 ml of pH 8.0 phosphate buffer, the digestion mixtures were further incubated for 24 hours at 37^{0}C.Enzyme blanks were prepared by incubation under the described conditions with the protein sample omitted.

After completion of the assay, undigested protein was precipitated by addition of 5 ml of 10 per cent trichloroacetic acid. This was centrifuged at 3500 rpm for 20 minutes, filtered and the supernatant was concentrated to 5 to 10 ml and nitrogen was estimated by microKjeldahl method.

Digestibility was calculated by the following expression:

$$\text{Per cent digestibility} = \frac{\text{Nitrogen in digested sample (supernatant)}}{\text{Nitrogen present in sample}} \times 100$$

4.2.6 Total ash

Total ash content of potato flour samples was determined by **AOAC (1975)** method.

3.4.2.7 Minerals

For estimation of minerals-calcium, phosphorus and iron in potato flour samples, ash solution was prepared according to the method of **AOAC (1975)**.

3.4.2.7.1 Preparation of ash solution

The total ash obtained from ten grams of potato flour sample, as indicated in 3.4.2.6, was used to prepare ash solution. 5 ml of dilute hydrochloric acid (1 : 1) was added to ash and mixture was evaporated to dryness on a boiling water bath. The residue so obtained was dissolved by adding 2 ml of dilute hydrochloric acid and heated for 5 minutes (on water bath) with watch glass on dish. Watch glass was washed off with water and the ash solution was then filtered into 100 ml. volumetric flask using Whatman No. 42 filter paper. After cooling, the volume was made upto 100 ml with distilled water and suitable aliquots were used for the estimation of calcium, phosphorus and iron.

3.4.2.7.2 Calcium

Calcium content of the flour samples was determined by titrimetric method of **AOAC (1975)**.

Procedure

A 20 ml aliquot of the ash solution was taken in a 250 ml conical flask. Eight to ten drops of bromocresol green indicator solution was added, followed by addition of sufficient 20 per cent sodium acetate solution, until the solution turned blue (pH = 4.8 – 5.0). It was covered with a watch glass and heated to boiling. To this was added, 3 per cent oxalic acid drop wise until the colour of solution turned green (pH = 4.4 – 4.6). Again the solution was boiled for 1-2 minutes and allowed to stand overnight.

The supernatant solution was filtered through Whatman number 42 filter paper. The conical flask, precipitate and filter paper were washed with 50 ml of dilute ammonium hydroxide solution (NH_3 : H_2O = 1 : 50), using wash bottle delivering small portions at a time. The filter paper was washed with a mixture of 125 ml water and 5 ml concentrated sulphuric acid, breaking the tip of filter paper, collecting the washings in original conical flask. It was then heated to 90^0C and titrated with 0.1N potassium permanganate solution until pink colour appeared, followed by addition of filter paper and titration was continued until colour re-appeared. A blank was also run simultaneously using distilled water in place of ash solution and corrections were made.

Calcium content was calculated as follows :

1 ml of 0.1 N $KMnO_4$ = 2 mg calcium

mg calcium per 100 g of sample = $2 \times (A-B) \times V/V_1 \times 100/W$

Where,

W = Weight of sample

V = Volume of ash solution made

V_1 = Volume of aliquot used

A = Titre value for sample

B = Titre value for blank

3.4.2.7.3 Phosphorus

Phosphorus content in the samples was estimated colorimetrically according to the procedure described by **Ranganna (1994)**.

Procedure

One ml of ash solution and five ml of molybdate reagent were taken in a 50 ml volumetric flask. To this, 2 ml of amino-naphthol-sulphonic acid solution was added, mixed well and volume made upto 50 ml using distilled water. This was allowed to stand for ten minutes. Blank was also prepared similarly, using water in place of sample. The blue colour developed was measured at 650 nm using Spectronic-20 (Bausch and Lomb).

Standard curve

For the preparation of standard curve, 10 ml of standard potassium phosphate solution was diluted to 50 ml with distilled water (1 ml = 0.02 mg P). Aliquots of this solution were pipetted from 5 to 40 ml into 50 ml. volumetric flasks. Five ml. of molybdate

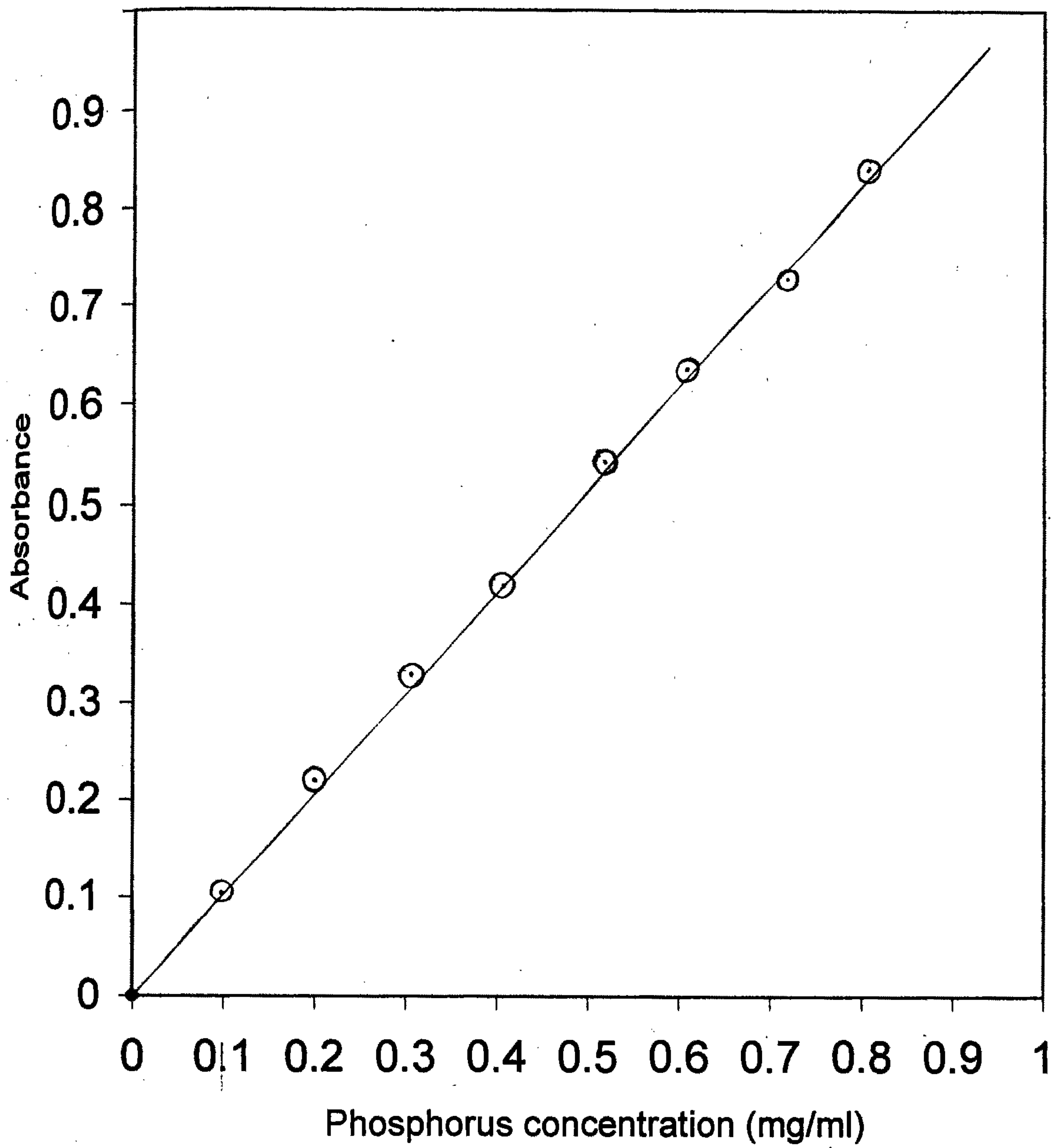


Figure 3.3: Standard curve for phosphorus

reagent was added to the flasks and mixed well. Then 2 ml of amino naphthol sulphonic acid solution was added, mixed well and volume made upto 50 ml. The blue colour developed was measured as in samples. The concentration was plotted against absorbance and phosphorus content of the sample read from the calibration curve (fig. 3.3).

The phosphorus content was calculated as follows :

$$\text{Phosphorus (P) (mg/100g)} = \frac{\text{mg of P in the aliquot of ash solution taken for estimation} \times \text{Total volume of ash solution}}{\text{ml of ash solution taken for estimation} \times \text{Weight of sample taken for ashing}} \times 100$$

3.4.2.7.4 Iron

The total iron content in potato flour was determined colorimetrically using the method of **AOAC (1975)**.

Procedure

Three test tubes were taken and labelled as blank, standard and ash. In each of the three test tubes, 10 ml of water blank, working iron standard and ash solution were taken respectively. 1 ml of saturated potassium persulphate followed by 2 ml of 3 N potassium thiocyanate solution were added in all tubes and the red colour developed was measured within 20 minutes at 560 nm (green filter) using colorimeter. Iron content was calculated using the following formula :

$$\text{Iron content (mg per 100 g)} = C_S \left[\frac{R_S - R_B}{R_A - R_B}\right] \times \frac{V}{V_1} \times \frac{100}{W}$$

Where,

C_S= Concentration of reading iron standard (0.01mg iron/ml)

R_S = Colorimeter reading for working iron standard

R_B = Colorimeter reading for blank

R_A = Colorimeter reading for ash solution

V = Total volume made of ash solution

V_1 = Volume used for colour development

W = Weight of sample

3.4.2.8 Ascorbic acid

Among vitamins, the ascorbic acid content of potato flour was estimated by 2, 6-Dichlorophenol-Indophenol visual titration method using **AOAC (1975)**.

Procedure

1. Standardization of dye

A mixture of 5 ml of standard ascorbic acid solution (.1 mg/ml) and 5 ml of metaphosphoric acid-acetic acid solution was taken and titrated rapidly with the dye solution to a pink colour which was stable atleast for fifteen seconds. The dye factor, that is, mg of ascorbic acid per ml of the dye was determined using the formula :

$$\text{Dye factor} = \frac{0.5}{\text{Titre value}}$$

2. Preparation of sample

Ten grams of sample was blended with HPO_3-HOAC solution and volume was made upto 100 ml with the same solution, and then filtered.

3. Assay of extract

An aliquot of 10 ml of the HPO_3-HOAC extract of the sample was titrated with the standard dye to a faint pink end point.

The ascorbic acid content in the sample was calculated using the following expression :

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre value} \times \text{dye factor} \times \text{volume made up}}{\text{Aliquot of extract taken for estimation} \times \text{weight of sample}} \times 100$$

3.4.3 Microbial load

Total bacterial count and coliform count of the potato flour were determined using plate count method as given in "Compendium of Methods for the Microbiological Examination of Foods" **(APHA, 1976)**.

3.4.3.1 Total bacterial count (plate count)

3.4.3.1.1 Preparation and sterilization of medium

Plate count agar was used to determine the total bacterial count 4.60 grams of plate count agar was suspended in 200 ml distilled water and then boiled to dissolve the medium completely, with pH adjusted to 7.0 ± 0.2. The medium was then sterilized by autoclaving it at 121^0C (15 lbs. pressure) for 15 minutes and then cooled to 45^0C before use. The composition of the medium is as follows :

Ingredients	Grams/litre
Tryptone	5.00
Yeast extract	2.50
Dextrose	1.00
Agar	15.00
Distilled water	1000.0 ml
Final pH (at 25^0C)	7.0 ± 0.2

3.4.3.1.2 Preparation of sample dilutions

Ten grams of potato flour was dissolved in 90 ml of sterile phosphate buffer (pH = 7.2). The suspension was then shaken thoroughly in a vortex mixer and subsequent dilutions were made using sterile phosphate buffer.

One ml of this flour suspension was aseptically transferred to sterile 9.0 ml of phosphate buffer tube, thus making 10^{-1} dilution. In the same fashion, dilutions of 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} were prepared.

3.4.3.1.3 Preparation of plates

Plates were prepared by pour plate method.

One ml from each dilution (10^{-2}, 10^{-3} , 10^{-4}, 10^{-5} and 10^{-6}) was transferred aseptically to sterile petri plates in triplicate. Then 10-15 ml of sterile plate count agar medium was poured in each of the plates. The contents were mixed thoroughly and properly by rotating the plates clockwise and anti clock wise. After solidification, the plates were then incubated at 37^0C for 48 hours.

3.4.3.1.4 Determination of total bacterial count

Thereafter, petri plates were taken out of the incubator and the colonies were counted using colony counter. The dilution plates showing the number of colonies in the statistical range of 30-300 were selected and average of the counts determined. The total plate count per gram of the sample was calculated by multiplying the average number of colonies by the dilution factor used.

Plate count per gram of sample = Number of colonies × dilution factor

3.4.3.2 Coliform count

3.4.3.2.1 Preparation and sterilization of medium

Violet Red Bile Agar (VRBA) was used to determined the coliform count. Exactly 8.30 grams of violet red bile agar was suspended in 200 ml distilled water and then boiled to dissolve the medium completely, with pH adjusted to 7.4 ± 0.2.

The medium was then cooled to 45^0C, prior to use and used as a plating medium. It was not sterilized. The composition of the medium is as follows :

Ingredients	Grams/lit
Peptone	7.00
Yeast extract	3.00
Bile Salts mixture	1.5
Lactose	10
Sodium chloride	5.0
Neutral red	.03
Crystal violet	.002
Agar	15.00
Distilled water	1000.0 ml
Final pH (at 25^0C)	7.4 ± 0.2

3.4.3.2.2 Preparation of sample dilutions

Ten grams of potato flour sample was dissolved in 90 ml of sterile phosphate buffer (pH = 7.2). The suspension was then shaken thoroughly and subsequent dilutions were made using sterile phosphate buffer.

One ml of this flour suspension was aseptically transferred to sterile 9.0 ml of phosphate buffer tube, thus making 10^{-1} dilution. In the same fashion, dilutions of 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} were prepared.

3.4.3.2.3 Preparation of plates

Plates were prepared by pour plate method.

One ml from each dilution (10^{-1} to 10^{-6}) was transferred aseptically to sterile petri plates in triplicate. Then 10-15 ml of VRBA medium was poured in each of the plates. The contents were mixed thoroughly and properly by rotating the plates clockwise and anti-clockwise. After solidification, the plates were incubated at 37^0C for 48 hours.

3.4.3.2.4 Determination of coliform count

Thereafter, the perti plates were taken out of the incubator and colonies counted using colony counter. The dilution plates showing the number of colonies in the statistical range of 30-300 were selected and average of the counts were determined. The total coliform count per gram of the sample was calculated by multiplying the average number of colonies by the dilution factor used.

Coliform count per gram of sample = Number of colonies × dilution factor

3.5 Product formulation

Different products were formulated by incorporating potato flour in different proportions in the traditional snacks. One traditional snack, each from the classes of baked goods, steamed product and deep fat fried product was selected for potato flour incorporation studies. The snacks selected were respectively, biscuit, idli and sev. The products were prepared from :

- Freshly prepared (control) i.e. zero time storage potato flour samples of each variety
- Potato flour samples of each variety stored at room temperature and refrigerated temperature for six months

3.5.1 Recipes

3.5.1.1 Biscuit (traditional recipe)

Biscuit was prepared by the "Traditional creamery method" as described by **Whitley (1970)**.

Ingredients	Quantity
White flour (maida)	100 g
Sugar (powdered)	28 g
Vegetable oil (groundnut refined)	24 ml
Skim milk powder	1.5 g
Glucose	1.5 g
Ammonium bicarbonate	0.75 g
Common salt	0.6 g
Baking powder	0.45 g
Sodium bicarbonate	0.30 g
Vanilla essence	0.03 ml
Water	23 ml

Note: Water content increased with increase in potato flour

Method

1. Sugar, fat and vanilla essence were creamed together.
2. To this creamed mixture, a well mixed blend of white flour, skim milk powder and baking powder was added alongwith water containing glucose, common salt, ammonium bicarbonate and sodium bicarbonate.

3. The contents were mixed further for two minutes to make the dough
4. Using a wooden rolling pin, the dough was sheeted on a platform to a uniform thickness of 2.5 mm.
5. Circular biscuits of 6.1 cm diameter were cut and baked for 20 minutes at 200^0C in a round oven.

Potato flour added biscuit

Potato flour (fresh, as well as stored for six months at room and refrigerated temperature) of each variety was incorporated in the above recipe to replace wheat flour at levels of 0, 10, 20, 30, 40 and 50 per cent in preparation of biscuit. All the other ingredients were constant except water and baking time.

3.5.1.2 Sev (traditional recipe)

Ingredients	Quantity
Besan	10 g
Red chillie (powder)	¼ tsp
Salt	½ tsp
Oil	½ tsp (hot) and for frying
Asafoetida	¼ tsp
Water	48 ml

Note: water requirement increased with increase in potato flour.

Method

1. Red chillie powder and asafoetida were mixed well with water into a thin paste.

2. Half teaspoon of hot oil and salt was added into flour and mixed well.
3. Measured water was added gradually and the mixture kneaded into a semi-stiff dough.
4. Oil was heated in a deep frying pan (at 170-175^{0}C) and forced the dough through a sev mould directly into hot oil.
5. Deep fried till golden brown and drained well.

Potato flour added sev

Potato flour (fresh as well as stored for six months at room and refrigerated temperature) of each variety was incorporated in the above recipe to replace besan at the levels of 0, 10, 20, 30, 40, 50 and 100 per cent for the preparation of sev. All the other ingredients were same except water which increased with the increase in level of potato flour.

3.5.1.3 Idli (traditional recipe)

Ingredients	Quantity
Wheat sooji	100 g
Curd	1 cup (125 g)
Green chillies	2 g
Curry leaves	10-15 leaves
Salt	½ tsp
Water	50 ml

Note: water content increased with increase in potato flour

Method

1. Wheat sooji was roasted lightly
2. Roasted sooji was added to curd and salt
3. Curry leaves and green chillies were chopped and added to the curd mixture
4. Enough water was added to form a drop batter
5. Mould of idli was filled with batter and steamed for 8-10 minutes

Potato flour added idli

Potato flour (fresh and stored for six months at room and refrigerated temperature) of each variety was incorporated in the above recipe to replace suji at levels of 0, 10,20,30, 40 and 50 per cent for preparation of idli. All the other ingredients were same except water which increased with the increase of potato flour.

3.6 Sensory quality evaluation of food products

The products viz. biscuits, sev and idli made by incorporating potato flour were evaluated for sensory quality characteristics such as appearance, colour, flavour, texture, taste and over all acceptability, by a panel consisting of ten judges.

Score card method was used to determine the sensory characteristics of the products made **(Amerine *et al.*, 1973)**. Appendix II shows score card for sensory evaluation of food products.

3.7 Nutritional value of food products

The sensory evaluation of the traditional snack items biscuit, sev and idli prepared by incorporating potato flour of each variety at different levels helped to determine the level, at which the food product was most acceptable. The data obtained after sensory evaluation was subjected to statistical analysis and the highest level having no difference with the control for each of the product was subjected to nutrient analysis. Before nutritional analysis idli samples were dried in hot air oven at 60 ^{0}C for 48 hours and ground to powdered form in a moisture free environment. Biscuit and sev samples were ground to powdered form. All the powdered samples were stored in air tight plastic containers through out the period of study.

Following parameters were determined for nutritional value of products:

3.7.1 Moisture

Estimated by the **AOAC (1975)** method as described in 3.4.2.1.

3.7.2 Protein

Determined by the **AOAC (1975)** procedure as in 3.4.2.2.

3.7.3 Total starch

Determined by colorimetric method as described by **Ranganna (1994)** in 3.4.2.4.

3.7.4 Fat

The fat content in food product samples was estimated according to the method of **AOAC (1975)**.

Two grams of sample was extracted for 16 hours in Soxhlet apparatus, using petroleum ether, with a boiling range of 40-60^{0}C. The fat containing petroleum ether in the receiver flask of the Soxhlet apparatus was transferred to weighed beakers in the hot air oven. The difference in the initial and final weight of the beakers was reported as fat content of the sample.

3.8 Statistical analysis

The entire data was analyzed on the PC-AT Compaq (Pentium II) computer system at G.B.Pant University of Agriculture & Technology, Pantnagar. Completely Randomised Design (CRD) was used to analyse the data of physico-chemical characteristics, nutritional value and microbial load of fresh and stored potato flour samples of three varieties. The relationship among characters analysed was studied by calculating correlation coefficient (r).

The data obtained from sensory evaluation of food products viz. biscuit, sev and idli was subjected to three factor Randomised Block Design (RBD). The analysis of variance, technique was used to sort out differences among the factors.

Paired 't- test' was used to determine the differences in the nutritional value of the most accepted potato flour incorporated food and the control sample **(Snedecor and Cochran, 1967)**.

Results and Discussion

4. RESULTS AND DISCUSSION

The present study was undertaken with a view to study the physico-chemical, nutritional, microbiological and storage characteristics of potato flour. The effect of incorporation of potato flour on quality characteristics of biscuits, sev and idli were also studied. The potato varieties used for the preparation of potato flour were 'OP-1', Kufri Sutlej ('K.Sutlej') and Kufri Ashoka ('K.Ashoka'). The results obtained on various characteristics are being presented and discussed under the following heads and sub-heads:

4.1 Processing characteristics

4.1.1 Boiling

4.1.2 Yield recovery of potato flour

4.2 Physico-chemical characteristics of potato flour

4.2.1 Colour

4.2.2 Water absorption capacity

4.2.3 Moisture sorption isotherm

4.2.4 Particle size index.

4.3 Nutritional value of potato flour

4.3.1 Moisture

4.3.2 Protein

4.3.3 Total ash

4.3.4 Total starch

4.3.5 Calcium

4.3.6 Total phosphorus

4.3.7 Total iron

4.3.8 Ascorbic acid

4.3.9 *In-vitro* protein digestibility

4.3.10 Total dietary fiber.

4.4 Microbial load of potato flour.

4.5 Sensory evaluation of potato flour incorporated food products.

4.6 Effect of potato flour incorporation on water requirement of different food products.

4.7 Nutritional value of potato flour incorporated food products.

4.1.1 Processing characteristics

4.1.1 Boiling

The boiled tubers of the potato varieties ('OP-1', 'K.Sutlej' and 'K. Ashoka') were observed for boiling and textural characteristics. The results are presented in Tables 4.1.1 and 4.1.2 respectively.

The colour of the boiled flesh of 'OP-1', 'K. Sutlej' and 'K.Ashoka' was observed as yellow, creamy white and creamy yellow respectively.

Literature evidences **(Hughes and Swain, 1962a; 1962b; Van Arsdel and Coopley, 1964; Pruthi, 1964; Burton, 1966; Smith, 1968; Hughes and Evans, 1969; Nagaich, 1977; Chaubey and Mazza, 1983 and Mondy and Gosselin, 1988)** showed that the colour of the boiled potato depends on concentration of total phenols. According to Burton (1989) colour of the cooked potatoes depends on the colour of the pigment present in the flesh.

Table 4.1.1: Boiling characteristics of potato varieties

Sl. No.	Variety	Colour	Disintegration	Consistency	Mealiness	Dryness	Structure
1.	OP-1	Yellow	None	Soft	Mealy	Slightly dry	Fine
2.	Kufri Sutlej	Creamy white	None	Slightly soft	Not mealy	Moist	Fine
3.	Kufri Ashoka	Creamy yellow	None	Slightly soft	Not mealy	Moist	Fine

Table 4.1.2 : Textural characteristics* of boiled potatoes

Sl.No.	Variety	Floury	Close	Waxy	Soapy
1.	OP-1		√		
2.	Kufri Sutlej			√	
3.	Kufri Ashoka			√	

* **Textural Characteristics**

1.Floury : Tubers often burst spontaneously and on application of fork break to pieces and crumble.

2. Close : Tubers do not burst, but readily break to the fork without crumbling.

3. Waxy : Flesh is firm and consistent and only breaks down by definite kneading.

4. Soapy : The consistency is the same as that of the waxy flesh, but in this the flesh appears watery and somewhat translucent.

None of the varieties showed any kind of disintegration. **Wood *et al.*, 1952; Sterling and Bettelheim, 1955; Wager, 1963; Burton 1989; Beirne, 1990** suggested that the texture of cooked potatoes is affected by the content of starch, pectic substances, dry matter, calcium ions and cell size of potato tubers.

According to **Lisinska and Leszczynski (1989)** consistency of the boiled potatoes may be affected by the mealiness, dryness and fine structure of the boiled potatoes. In this respect, because of the mealier texture, dryness and line structure, the variety 'OP-1' was found soft in consistency, whereas varieties 'K.Sutlej' and 'K.Ashoka' were rated as slightly soft.

The boiled tubers of the variety 'OP-1' were rated as mealy, whereas 'K.Sutlej' and 'K.Ashoka' both were rated as not mealy. The differences in the meatiness of the varieties in the present study may be attributed to the total starch content as this was high in variety

'OP-1', as reported by **Bretzlofe (1970); Warren and Woodman (1975); Hughes *et al.* (1975); Faulks (1986); Rose (1987); Meredith (1988); Burton (1989) and Beirne (1990).**

The boiled tubers of variety 'OP-1' were found to be slightly dry, whereas, 'K.Sutlej' and 'K.Ashoka' were observed as moist. The structure of the boiled potatoes was observed as fine for all the three varieties.

The results of the textural characteristics of boiled potato varieties, presented in table 4.1.2 revealed that the variety 'OP-1' was categorized as close textured and varieties 'K.Sutlej' and 'K.Ashoka' were observed as waxy. The texture of the tubers may be due to the differences in the proportions of amylose and amylopectin.

4.1.2 Yield recovery of potato flour

Data on raw, boiled and peeled potatoes, peel weight, flour weight and yield recovery of potato flour from the varieties 'OP-1', 'K.Sutlej' and 'K.Ashoka' have been shown in table 4.1.3. Results revealed that weight of raw and boiled potatoes remained same. Peel weight, weight of boiled flesh of tubers and weight of dried grate showed little differences among the varieties. The highest yield of potato flour was obtained from the variety 'K-Sutlej' (4.69 kg) followed by 'OP-1' (4.48 kg) and 'K.Ashoka' (4.10 kg). The percentage flour recovery was recorded as 16.17 in 'K.Sutlej', 15.45 in 'OP-1' and 14.14

in 'K.Ashoka' which was in accordance with the similar range of potato flour recovery (16.60 per cent) recorded by **Marwaha and Sandhu (1999). Marwaha (1999) and Waghmare *et al.* (1999),** respectively attributed the yield recovery of potato flour to the varietal dry matter content and smaller tuber sizes.

Table 4.1.3: Yield recovery of potato flour

Sl. No.	Parameter	Varieties		
		'OP-1'	'K.Sutlej'	'K.Ashoka'
1.	Raw weight (kg)	29.00	29.00	29.00
2.	Boiled weight (kg)	29.00	29.00	29.00
3.	Peel weight (kg)	0.75	0.97	0.90
4.	Boiled flesh (kg)	28.25	28.03	28.10
5.	Dried grate (kg)	4.67	4.92	4.37
6.	Flour weight (kg.)	4.48	4.69	4.10
7.	Per cent flour recovery	15.45	16.17	14.14

4.2 Physico-chemical characteristics of potato flour

4.2.1 Colour

The hue and value of fresh potato flour as well as that of the stored potato flour at room and refrigerated temperature for 3 and 6 months for the varieties 'OP-1', 'K.Sutlej' and 'K.Sutlej' and 'K.Ashoka' have been presented in Table 4.2.1. Results exhibited that the colour of flours did differ slightly in hue and value of all the varieties. The hue and value of variety OP-1 was recorded as 2.5y(8/4) while for varieties 'K.Sutlej' and 'K.Ashoka', it was observed as 5y(8/3) and 5y(8/4), respectively. However, all values were designated as pale yellow on **Munsell soil colour chart (1954).**

Pant and Kulshreshtha (1995) reported the flour colour among six potato varieties as pale yellow - 5y(8/4); 5y(3/4); 2.5y(8/4) to yellow – 2.5y(7/8), which is similar to the results obtained in the present investigation.

The results revealed that storage had no effect on colour of potato flour of all the three varieties, stored up to 6 months both at room and refrigerated temperature. The results are in accordance with the study conducted by **Vaidehi and Sunanda (1982),** who reported no changes in colour, flavour and odour of the potato flour stored for six months. **Nanda and Khanna (1988)** reported that the potato flour stored in air tight containers at room temperature for 3 weeks (21

Table 4.2.1 : Colour of potato flour

Variety	Fresh	3 months storage		6 months storage	
		Room temp.	Refrigerated temp.	Room temp.	Refrigerated temp.
OP-1	2.5y (8/4) (pale yellow)	2.5y (8/4) (pale yellow)	2.5y (8/4) (pale yellow)	2.5y (8/4) (pale yellow)	2.5y (8/4) (pale yellow)
K.Sutlej	5y (8/3) (pale yellow)	5y (8/3) (pale yellow)	5y (8/3) (pale yellow)	5y (8/3) (pale yellow)	5y (8/3) (pale yellow)
K.Ashoka	5y (8/4) (pale yellow)	5y (8/4) (pale yellow)	5y (8/4) (pale yellow)	5y (8/4) (pale yellow)	5y (8/4) (pale yellow)

days) did not develop any adverse colour, flavour or taste, which is in confirmance with the results of present investigation for colour of potato flour.

4.2.2 Water absorption capacity

Water absorption capacity represents the weight of water taken up per gram of flour **(Molina *et al.*, 1977)**. The water absorption capacity varied significantly ($p<0.05$) with the varieties (Table 4.2.2). The highest (346.67 per cent) water absorption capacity was recorded for variety 'OP-1' and the lowest (286.67 per cent) for the variety 'K. Ashoka'.

Variety 'OP-1' showed a decreasing trend in water absorption capacity with increase in storage time (up till 6 months storage) Decrease in refrigerated temperature was less as compared to room temperature. A significant ($p<0.05$) decrease in water absorption capacity was observed after 3 months and 6 months storage at room temperature. At refrigerated temperature, a significant ($p<0.05$) difference was seen only after 6 months storage. Variety 'K.Sutlej' also showed a similar trend in water absorption capacity except that there occurred a significant ($p<0.05$) difference between room temperature and refrigerated temperature at 3 months storage. 'K.Ashoka' had a similar trend like that of 'OP-1'.

Purves and Scrively (1975) reported that the water absorption capacity of potato flour could be attributed to the varietal differences

Table 4.2.2: Water absorption capacity* (%) of potato flour

Variety	Fresh	3 months storage		6 months storage		Mean	SEm	C.D. (5%)
		Room Temp.	Refrigerated Temp.	Room Temp.	Refrigerated Temp.			
OP-1	346.67 X •	336.67 •	342.00	332.00 •	335.33 •	338.53	1.76	5.56
K. Sutlej	336.67 X •	328.00 •	334.00 •	321.33	323.33	328.67	1.76	5.56
K. Ashoka	286.67 •	276.00 •	279.33	270.67 •	274.67 •	277.47	3.16	9.94
Mean	323.34	313.56	318.44	308.00	311.11			
SEm	1.16	1.02	1.15	1.01	1.15			
C.D. (5%)	3.51	3.52	3.99	3.52	3.99			

* All values are average of triplicate

X -Significant at varietal level
• -Significant at condition level

in free starch levels and composition of starch. A similar, direct relationship between water absorption capacity and starch content was reported by **Katara (1983)**. Significant positive correlation (r=0.516) was observed in between water absorption capacity and starch content in the present investigation (Table 4.2.4).

The decrease in water absorption capacity could be attributed to the increase in the moisture content on storage (as evident from discussion under 4.3.1) as suggested by **Tomkins *et al.* (1944)** and **Burton (1945)**.

4.2.3 Moisture Sorption Isotherm

Sorption isotherm is a relationship between the moisture content of the product as a function of equilibrium with relative humidity at a single temperature. The equilibrium related humidity of the product is a better indicator, than the moisture content for storage, since it is a measure of the availability of water to microorganism associated with the product **(Hunt and Pixton, 1974)** i.e. the equlibrium relative humidity of the biological activity of the product at that temperature.

The sorption isotherm of fresh as well as stored flours (stored for 3 and 6 months at room and refrigerated temperature) for the three potato varieties are depicted in Figure 4.1, 4.2 and 4.3. The curves of each variety show that above 50 per cent relative humidity,

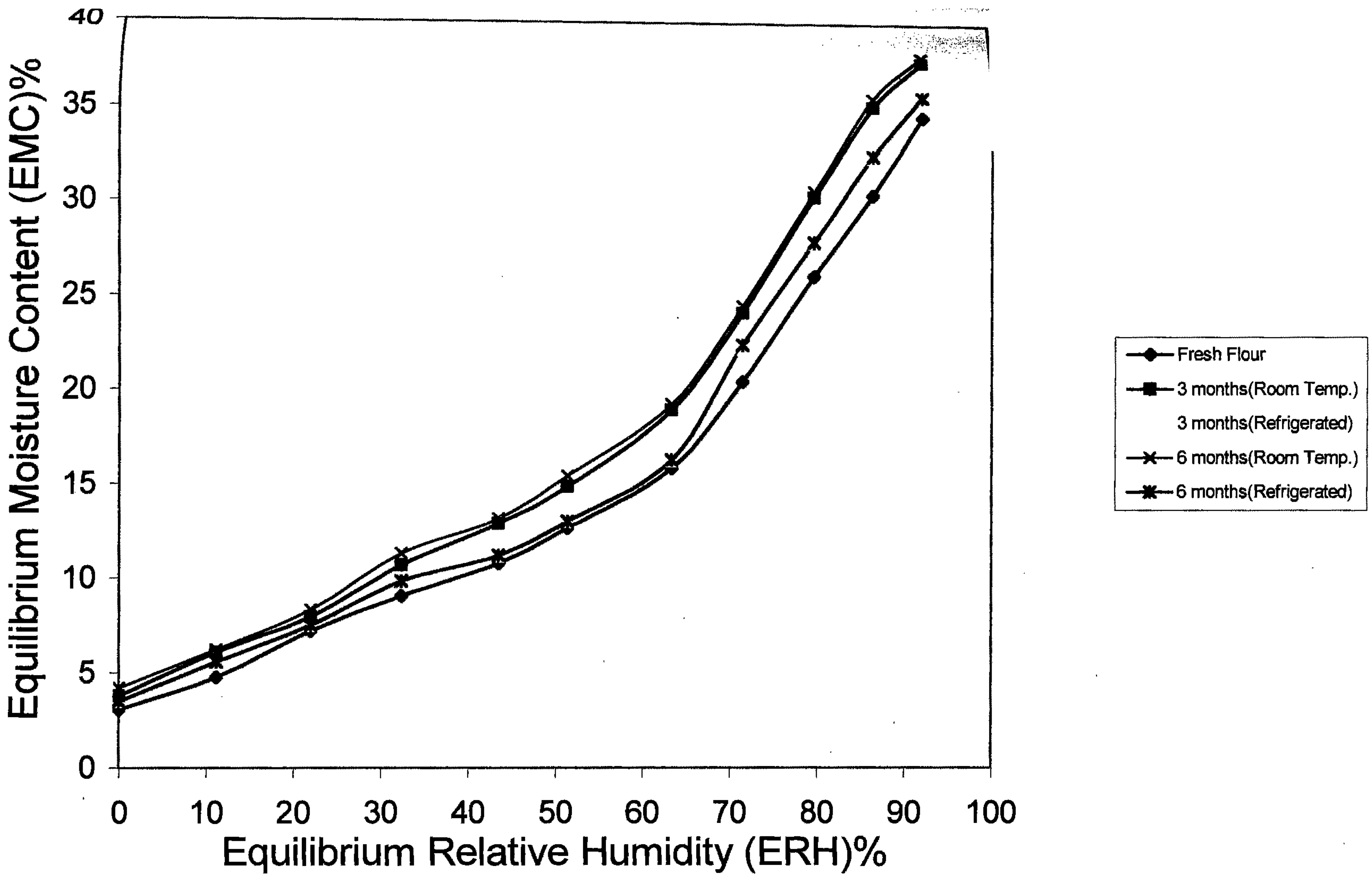


Figure 4.1: Moisture Sorption Isotherm (OP-1)

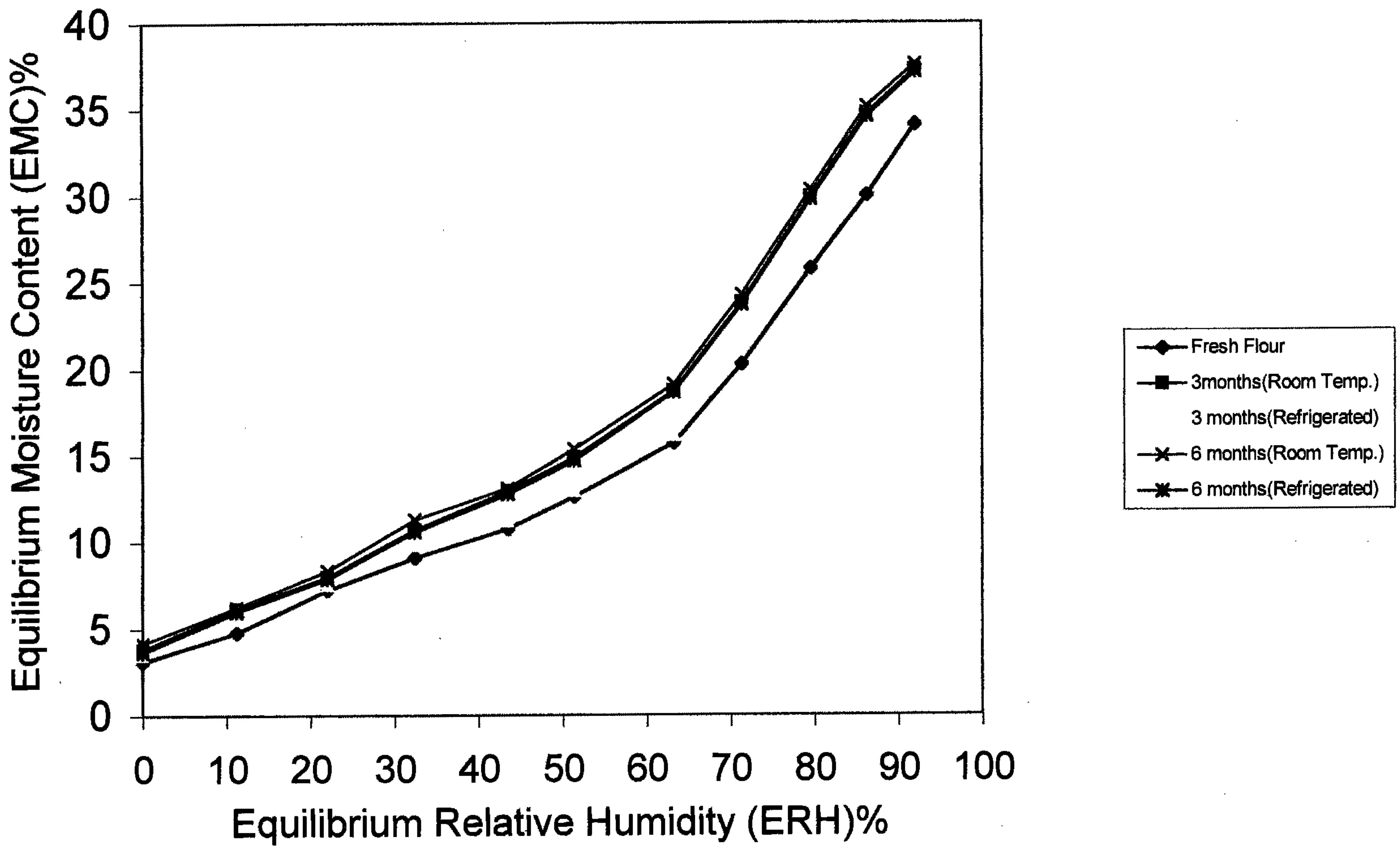


Figure 4.2: Moisture Sorption Isotherm (K.Sutlej)

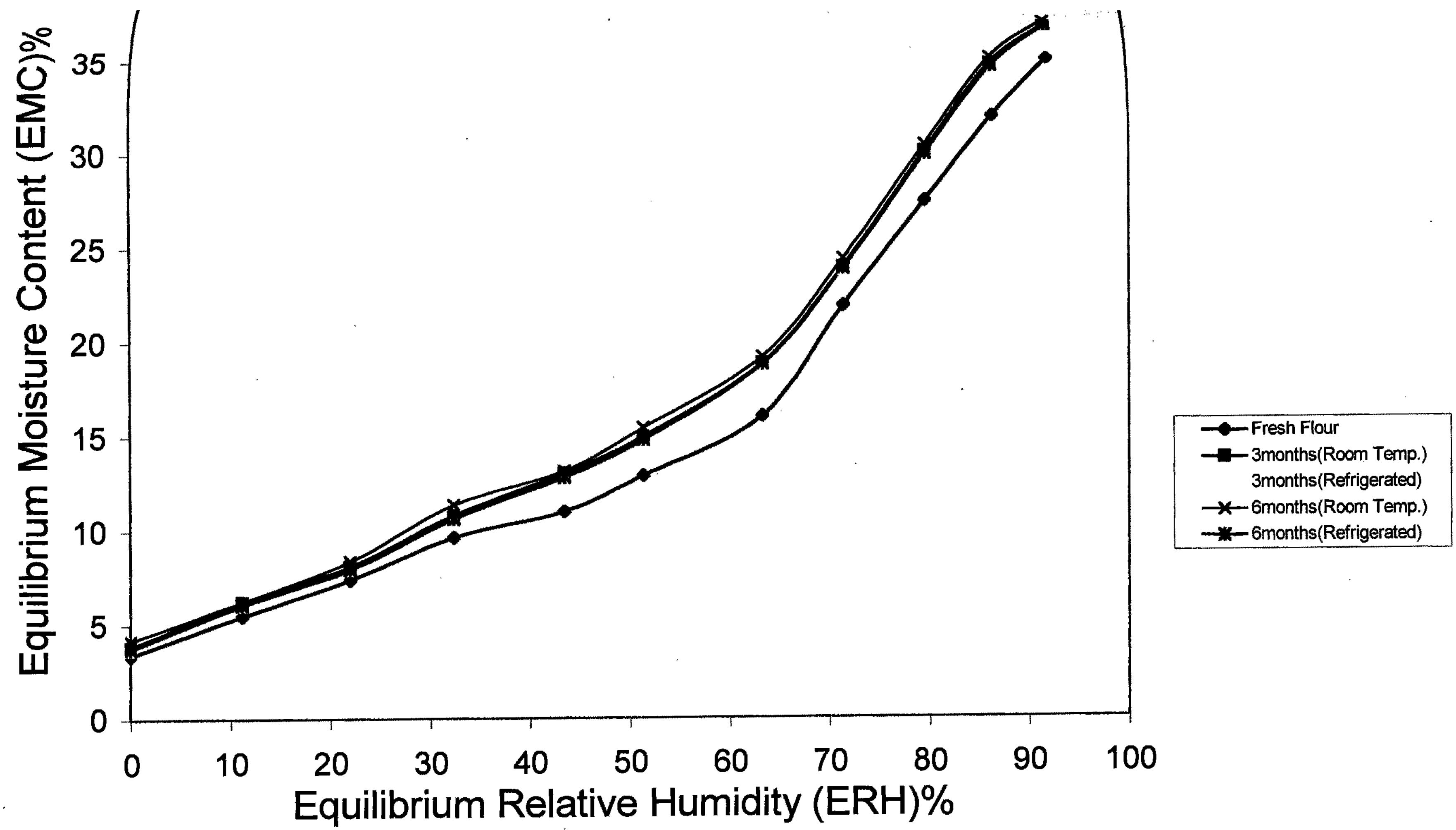


Figure 4.3: Moisture Sorption Isotherm (K.Ashoka)

D	Potato flour stored at different relative humidities: showing moistness and caking

E	Potato flour stored at high relative humidities: showing mould growth

there is a sharp increase in equilibrium moisture content and adverse changes such as caking and mould growth were observed. This suggested that potato flour can be stored safely upto 50 per cent relative humidity without affecting its quality. The equlibrium relative humidity, its corresponding moisture content and changes occurred during the experiment for potato flour of the three varieties are given in Appendices III, IV and V.

4.2.4 Particle size index

Results (Table 4.2.3) on particle size index of potato flour revealed that variety 'OP-1' (36.07) differed significantly ($p<0.05$) with varieties 'K.Sutlej' (34.91) and 'K.Ashoka' (34.84), while later two varieties did not show any significant difference with each other. The results are in confirmance with the particle size index ranging from 32.08 to 36.02 as reported by **Pant and Kulshreshtha (1995).** Statistical analysis showed that storage had no effect on the particle size index of the flours stored at room and refrigerated temperature for both 3 and 6 months. Particle size index, a parameter inversely related to fineness of flour **(Bedolla and Rooney, 1984),** also affects water absorption capacity **(Khan *et al.,* 1982). Pant and Kulshreshtha (1995)** reported a significant positive correlation between water absorption and particle size index. A similar significant positive correlation ($r = 0.63$) between water absorption capacity and particle size index was recorded in the present investigation (Table 4.2.4).

Table 4.2.3: Particle size index* of potato flour

Variety	Fresh	3 months storage		6 months storage		Mean	S.Em	C.D. (5%)
		Room Temp.	Refrigerated Temp.	Room Temp.	Refrigerated Temp.			
OP-1	36.07 ×	35.95	36.03	35.92	35.99	35.99	0.54	1.42
K. Sutlej	34.91	34.83	34.86	34.80	34.81	34.84	0.44	1.05
K. Ashoka	34.84	34.75	34.80	34.72	34.79	34.78	0.31	0.99
Mean	35.27	35.18	35.23	35.15	35.20			
SEm	0.12	0.10	0.24	0.52	0.40			
C.D. (5%)	0.40	0.34	0.84	1.81	1.39			

* All values are average of triplicate

X -Significant at varietal level

4.3 Nutritional value of potato flour

4.3.1 Moisture

It is evident from the Table 4.3.1 that the varieties had almost equal moisture content. The mean values of moisture content were reported as 8.08 per cent for 'OP-1', 8.10 per cent for 'K.Sutlej' and 8.48 per cent for 'K.Ashoka'.

The results revealed an increasing trend in the moisture content of potato flours, with increase in storage time for all the three varieties. However, increase in moisture content was less at refrigerated temperature as compared to room temperature, for all the varieties. For variety 'OP-1', a significant ($p< 0.05$) increase in moisture content was observed after 3 months and 6 months storage at room and refrigerated temperature. A significant increase ($p<0.05$) in six months stored samples over the three months stored samples was observed at room temperature only.

Variety 'K.Sutlej' also showed a similar trend in moisture content during storage variety 'K.Ashoka' showed a significant ($p<0.05$) increase in moisture content after 3 months and 6 months storage at room temperature only.

The values of moisture content in the present investigation are in accordance with the earlier findings reported by **Yanez *et al.* (1981); Vaidehi and Sunanda (1982); Willard and Hix (1987); Nanda**

Table 4.3.1: Moisture* content (%) of potato flour

Variety	Fresh	3 months storage		6 months storage		Mean	SEm	CD (5%)
		Room Temp.	Refrigerated Temp.	Room Temp.	Refrigerated Temp.			
OP-1	8.08 •	8.93 •	8.62 •	9.66 •	8.68 •	8.79	0.14	0.44
K. Sutlej	8.10 •	9.12 •	8.74 •	9.81 •	8.82 •	8.92	0.13	0.39
K. Ashoka	8.48 •	9.36 •	8.83	9.92 •	8.97	9.11	0.17	0.54
Mean	8.22	9.14	8.73	9.80	8.82			
SEm	0.32	0.02	0.02	0.03	0.04			
C.D. (5%)	1.12	0.06	0.08	0.09	0.13			

* All values are average of triplicate

-Significant at condition level

and **Khanna (1988); Rai (1990); Petelle *et al.* (1995),** who all showed a range of moisture content from 6.10 to 8.00 per cent.

Sagar and Roy (1997) reported that gain in moisture content occurred in potato powder with increase in storage time (from 3 to 12 months of storage) both at room temperature and cool storage, which is also revealed in the present study. The values reported by **Sunanda and Vaidehi (1982)** for an increase in moisture content of potato flour over a period of six months from 8.00 per cent to 9.60 per cent, are close to the values attained in the present investigation.

4.3.2 Protein

Results on the protein content of potato flour as shown in Table 4.3.2 reveal that variety 'OP-1' with a protein content of 10.48 per cent and variety 'K.Sutlej' with a protein content of 10.33 per cent differed significantly ($p<0.05$) from that of 'K.Ashoka' (9.24 per cent).

The values of protein content in the present investigation are in agreement with the protein content ranging from 6.00 to 12.00 per cent, as reported by **Treadway *et al.* (1950); Willard (1967); Chandrashekara and Shurpalekar (1983); Nanda and Khanna (1988); Gahlawat and Sehgal (1998).**

The results revealed that storage of flours upto 6 months (room and refrigerated temperature) had no effect on protein content in all the three varieties.

Table 4.3.2: Protein content* (%) of potato flour

Variety	Fresh	3 months storage		6 months storage		Mean	SEm	CD (5%)
		Room Temp.	Refrigerated Temp.	Room Temp.	Refrigerated Temp.			
OP-1	10.48 X	10.27	10.35	10.23	10.32	10.33	0.12	0.40
K. Sutlej	10.33 X	10.26	10.30	10.21	10.25	10.27	0.07	0.22
K. Ashoka	9.24	9.17	9.21	9.11	9.15	9.18	0.30	0.95
Mean	10.02	9.90	9.95	9.85	9.91			
SEm	0.20	0.16	0.20	0.21	0.20			
C.D. (5%)	0.69	0.54	0.69	0.74	0.67			

* All values are average of triplicate on dry weight basis

X -Significant at varietal level

The findings of the present study are in accordance with **Kulkarni *et al.* (1993)** who reported that storage had no significant effect upon composition of the potato flour.

4.3.3 Total ash

The total ash content of potato flour has been presented in Table 4.3.3. Significant ($p<0.05$) varietal differences have been observed with the highest ash content of 3.09 per cent in variety 'OP-1' which was at par with the total ash content of 'K.Sutlej' (2.83 per cent) and lowest value of 2.56 per cent was recorded in variety 'K.Ashoka'.

The values of the ash content of potato flour ranging from 2.35 per cent to 3.09 per cent in the present investigation are within the range reported by other authors **(Treadway *et al.*, 1950; Yanez *et al.*, 1981; Chandrashekara and Shurpalekar, 1983; Nanda and Khanna, 1988)**.

As regards the effect of storage, no significant effect was observed on the ash content of all the three varieties both at 3 months and 6 months storage at both the conditions.

4.3.4 Total starch

Results on starch content of potato flour presented in the Table 4.3.4 shown that the highest starch content was recorded in variety 'OP-1' (78.04 g/100 g) and this was significantly higher ($p<0.05$) than

Table 4.3.3: Total ash* content (%) of potato flour

Variety	Fresh	3 months storage		6 months storage		Mean	SEm	CD (5%)
		Room Temp.	Refrigerated Temp.	Room Temp.	Refrigerated Temp.			
OP-1	3.09 X	2.74	2.81	2.80	2.77	2.84	0.12	0.39
K. Sutlej	2.83	2.69	2.79	2.64	2.73	2.74	0.19	0.59
K. Ashoka	2.56	2.38	2.49	2.35	2.44	2.44	0.07	0.24
Mean	2.83	2.60	2.70	2.60	2.65			
SEm	0.14	0.03	0.01	0.02	0.02			
C.D. (5%)	0.51	0.11	0.05	0.09	0.09			

* All values are average of triplicate on dry weight basis

X -Significant at varietal level

Table 4.3.4: Total starch* content (%) of potato flour

Variety	Fresh	3 months storage		6 months storage		Mean	SEm	CD (5%)
		Room Temp.	Refrigerated Temp.	Room Temp.	Refrigerated Temp.			
OP-1	78.04	77.37	77.44	77.17	77.32	77.46	0.45	1.42
K. Sutlej	76.39	75.49	75.57	74.66	74.90	75.40	0.62	1.91
K. Ashoka	75.57	74.73	74.82	74.38	74.76	74.85	0.59	1.82
Mean	76.67	75.86	75.94	75.39	75.66			
SEm	0.25	0.34	0.29	0.30	0.35			
C.D. (5%)	0.97	1.24	1.01	1.09	1.22			

* All values are average of triplicate on dry weight basis

that of varieties 'K.Ashoka' (75.57 g/100 g) and 'K.Sutlej' (76.39 g/100 g).

The range of the starch content of the varieties studied in the present study are close to the starch content of potato flour as reported by **Chandrashekara and Shurpalekar (1983)** as 81.20 per cent and a value of 77.65 per cent as reported by **Nanda and Khanna (1988).**

Like other components, no significant change in the starch content was observed, both at room and refrigerated temperature up to six months in all the three varieties.

A critical observance in the present study reveals a significant positive correlation (r=0.516) between the starch content and water absorption capacity. This finding is in confirmation with the earlier works reported by **Purves and Scrively (1975)** who attributed the water absorption capacity to the varietal differences in starch levels. Similarly, **Katara (1983)** has established a direct relationship between starch content and water absorption capacity, which is in agreement with the present study.

4.3.5 Calcium

The results on calcium content of potato flour are presented in Table 4.3.5. Variety 'OP-1' showed the highest calcium content of 21.76 mg/100 g which differed significantly ($p<0.05$) from varieties 'K.Sutlej' (18.14 mg/100 g) and 'K.Ashoka' (18.21 mg/100 g).

Table 4.3.5: Calcium* content (mg/100 g) of potato flour

Variety	Fresh	3 months storage		6 months storage		Mean	SEm	CD (5%)
		Room Temp.	Refrigerated Temp.	Room Temp.	Refrigerated Temp.			
OP-1	21.76 ×	21.26	21.72	21.13	21.58	21.49	0.39	1.23
K. Sutlej	18.14	17.94	18.11	17.45	18.03	17.93	1.65	5.20
K. Ashoka	18.21	17.98	18.14	17.86	18.10	18.06	1.65	5.22
Mean	19.37	19.06	19.32	18.81	19.24			
SEm	0.30	0.59	0.14	0.45*	0.09			
C.D. (5%)	1.03	2.04	0.97	1.57	0.82			

* All values are average of triplicate on dry weight basis

X -Significant at varietal level

The results of storage obtained revealed that storage had no significant effect upon calcium content of flour. **Kulkarni et al. (1993)** also reported that storage had no significant effect upon composition of potato flour. The values of calcium content of potato flour are somewhat lower to those reported by **Nanda and Khanna (1988)** as 30.16 mg per 100 g.

4.3.6 Total phosphorus

The total phosphorus content of potato flour samples varied significantly ($p<0.05$) with the varieties (Table 4.3.6). Variety 'OP-1' with a phosphorus content of (188.57 mg/100 g) differed significantly with that of 'K.Ashoka' (171.19 mg/100 g), but did not differ significantly with that of 'K.Sutlej' (177.73 mg/100 g).

The values of phosphorus content for potato flours in the present study are in accordance with the phosphorus content (177.40 mg/100 g) as reported by **Nanda and Khanna (1988).**

Storage of potato flours had no significant effect on phosphorus content, just as reported by **Kulkarni et al. (1993).**

4.3.7 Total iron

The total iron content of potato flours as shown in Table 4.3.7 clearly revealed that all the 3 varieties differed significantly with

Table 4.3.6: Phosphorus* content (mg/100 g) of potato flour

Variety	Fresh	3 months storage		6 months storage		Mean	SEm	CD (5%)
		Room Temp.	Refrigerated Temp.	Room Temp.	Refrigerated Temp.			
OP-1	188.57 X	188.13	188.45	187.78	188.31	188.25	3.54	11.16
K. Sutlej	177.73	175.62	176.96	175.42	176.67	176.48	2.85	8.97
K. Ashoka	171.19	170.27	170.63	168.99	170.29	170.27	2.73	8.61
Mean	179.16	178.01	178.68	177.40	178.42			
SEm	3.45	3.24	3.30	3.10	3.21			
C.D. (5%)	11.73	11.21	11.35	10.98	11.19			

* All values are average of triplicate on dry weight basis

X -Significant at varietal level

Table 4.3.7: Total Iron* content (mg/100 g) of potato flour

Variety	Fresh	3 months storage		6 months storage		Mean	SEm	CD (5%)
		Room Temp.	Refrigerated Temp.	Room Temp.	Refrigerated Temp.			
OP-1	3.93 X	3.81	3.85	3.80	3.82	3.84	0.04	0.15
K. Sutlej	3.63	3.55	3.58	3.51	3.53	3.56	0.03	0.12
K. Ashoka	3.89 X	3.82	3.85	3.78	3.80	3.83	0.05	0.15
Mean	3.82	3.73	3.76	3.70	3.72			
SEm	0.20	0.04	0.34	0.03	0.02			
C.D. (5%)	0.11	0.13	0.12	0.09	0.08			

* All values are average of triplicate on dry weight basis

X -Significant at varietal level

each other, with the similar iron content in both varieties 'OP-1 (3.93 mg/100 g) and 'K.Ashoka' (3.89 mg/100 g) and these values differed significantly ($p<0.05$) from that of 'K.Sutlej' (3.63 mg/100 g).

The results of iron content in the present study are close to the values reported by **Nanda and Khanna (1988)** as 3.95 mg/100g. The results revealed that storage of potato flour up to 6 months, had no significant effect upon the iron content.

4.3.8 Ascorbic acid

The results of ascorbic acid content of potato flours are presented in Table 4.3.8. Varietal variations in the ascorbic acid content was observed for potato flours. Varieties 'OP-1' (8.70 mg/100g) and 'K.Ashoka' (7.12 mg/100 g) differed significantly ($p<0.05$) from variety 'K.Sutlej' (6.96mg/100g).

Variety 'OP-1' showed a decreasing trends in the ascorbic acid content with increase in storage time. The losses of ascorbic acid were less at refrigerated temperature as compared to room temperature. A significant decrease ($p<0.05$) in ascorbic acid content was observed after 3 months and 6 months storage both at room temperature and refrigerated temperature. Significant ($p<0.05$) differences were also observed in between room and refrigerated temperature, both at 3 months and 6 months storage. The other two varieties viz. 'K.Sutlej' and 'K.Ashoka' also showed a similar trend.

Table 4.3.8: Ascorbic acid* content (mg/100 g) of potato flour

Variety	Fresh	3 months storage		6 months storage		Mean	SEm	CD (5%)
		Room Temp.	Refrigerated Temp.	Room Temp.	Refrigerated Temp.			
OP-1	8.70 X •	7.99 •	8.24 •	7.20 •	7.52 •	7.93	0.06	0.18
K. Sutlej	6.96 •	6.16 •	6.52 •	5.43 •	5.77 •	6.17	0.03	0.09
K. Ashoka	7.12 X •	6.55 •	6.81 •	5.85 •	6.22 •	6.51	0.02	0.06
Mean	7.59	6.90	7.19	6.16	6.50			
SEm	0.25	0.08	0.01	0.01	0.01			
C.D. (5%)	0.88	0.27	0.04	0.02	0.04			

* All values are average of triplicate on dry weight basis

X -Significant at varietal level
• -Significant at condition level

The ascorbic acid content values of potato flour in the present investigation are close to the values (5.67 mg/100 g) as reported by **Nanda and Khanna (1988).**

In the present investigation, storage seemed to have a decrease in the ascorbic acid content with increase in storage time. Similar findings were reported by **Wang *et al* (1992) and Vencken and Ebbenhorst (1990)** who reported that ascorbic acid content of the flaked product decreased during 6 months of storage at 20 °C. **Roy Chaudhari *et al.* (1963a)** also observed vitamin C loss during 6 months of storage of potato flour in sealed polythene bags at 37 °C. **Wills and Silalahi (1990)** reported that the potato crisps stored at 2 °C for 3 months showed little loss of vitamin C as compared to those stored at 20 °C, 30 °C and 50 °C for 3 months. The rate of loss increased exponentially as the temperature increased. The results of the present study are also in accordance with it, as results clearly show that loss of ascorbic acid was less at refrigerated temperature as compared to room temperature. Losses were more at 6 months of storage.

4.3.9 *In-Vitro* protein digestibility

High quality proteins are those that are well digested and contain all the essential amino acids necessary for protein synthesis *in vivo* and in a ratio that supports growth. Since modern theories of

Table 4.3.9: *In vitro* protein digestibility* (%) of potato flour

Variety	Fresh	3 months storage		6 months storage		Mean	SEm	CD (5%)
		Room Temp.	Refrigerated Temp	Room Temp.	Refrigerated Temp.			
OP-1	77.00 X	75.63	76.88	75.09	76.08	76.14	0.64	2.02
K. Sutlej	75.89 X	74.95	76.67	73.87	75.17	75.31	0.64	2.03
K. Ashoka	72.85	71.74	73.94	70.38	72.50	72.28	0.94	2.96
Mean	75.25	74.11	75.83	73.11	74.58			
Sem	0.65	0.58	0.74	0.56	0.61			
C.D. (5%)	2.24	1.98	2.58	1.94	2.07			

* All values are average of triplicate on dry weight basis

X -Significant at varietal level

protein synthesis require that all the amino acid be available at the same time and as amino acids are liberated from proteins *in vivo* only after hydrolysis by digestive enzymes, it would seem that a measure of the amount of eight essential amino acids released by digestive enzymes *in-vitro* should give a good estimate of protein quality **(Stahmann and Woldegiorgis, 1975).**

The results on *in-vitro* protein digestibility of potato flour as presented in Table 4.3.9 clearly show that significant varietal variations exist for *in-vitro* protein digestibility. Varieties 'OP-1' (77.00 per cent) and 'K.Sutlej' (75.89 per cent) showed non-significant differences in in-vitro protein digestibility, whereas both differed significantly from 'K.Ashoka' (72.85 per cent).

The values of *in-vitro* protein digestibility in the present investigation are close to the values (73.27 per cent) reported by **Gahlawat and Sehgal (1998).**

Statistical analysis of the data on storage of potato flour, both at room and refrigerated temperature up to 6 months, suggest that *in vitro* protein digestibility did not change with storage.

4.3.10 Total dietary fiber

Dietary fiber occurs naturally in all plants and is available for the human diet through a wide variety of food sources such as cereal

Table 4.3.10: Total dietary fiber* (g/100 g)of potato flour

Variety	Fresh	3 months storage		6 months storage		Mean	SEm	CD (5%)
		Room Temp.	Refrigerated Temp.	Room Temp.	Refrigerated Temp.			
OP-1	6.60 X	6.21	6.27	6.09	6.10	6.25	0.22	0.70
K. Sutlej	6.25	6.08	6.22	5.91	6.02	6.10	0.21	0.66
K. Ashoka	6.47 X	5.89	5.93	5.86	5.88	6.01	0.20	0.62
Mean	6.44	6.06	6.14	5.95	6.00			
SEm	0.06	0.03	0.04	0.09	0.08			
C.D. (5%)	0.25	0.12	0.17	0.34	0.28			

* All values are average of triplicate on dry weight basis

X -Significant at varietal level

products, vegetables, fruits, prepared foods (which may include gums or other fiber additives) and dietary supplements **(Dreher, 1987).** Total dietary fiber has been termed as roughage, bulk, bran, fiber, plant residues, unavailable carbohydrates and plantix. Dietary fiber is defined as polysaccharides and lignin present in our diet that are not digested by endogenous secretions of the human digestive tract. **(Trowell *et al.*, 1976).** The importance of dietary fiber was appreciated over the last few decades, as it emerged as a leading factor in the prevention and treatment of chronic diseases **(Anderson *et al.*, 1994)**.

As total dietary fiber consists of both the insoluble dietary fiber (IDF) and soluble dietary fiber (SDF), statistical analysis was performed on total dietary fiber, the results of which are presented in Table 4.3.10. Varieties 'OP-1' (6.60 g/100 g) and 'K.Ashoka' (6.47g/100g) showed similar dietary fiber content. However, variety OP-1 differed significantly ($p<0.05$) from that of 'K.Sutlej' (6.25 g/100 g).

The dietary fiber values in present investigation are in accordance with the values reported by **Southgate and White (1981)** as 6.40 g/100 g to 26.3 g/100 g and as reported by **Theander and Aman (1981)** as 6.0 g/100 g.

Statistical analysis of the data revealed no significant change in the dietary fiber content on storage upto six month in all the three varieties. The results are in accordance with the findings of **Kulkarni *et al.* (1993)** who reported that storage had no effect on composition of potato flour.

4.4. Microbial load of potato flour

Results on microbial counts of potato flour stored upto six month under room and refrigerated temperature are presented in the Table 4.4. Lowest bacterial count was observed in variety 'OP-1' (1.65×10^3) which differed significantly ($p<0.05$) from varieties 'K.Sutlej' (1.76×10^3) and 'K.Ashoka' (1.74×10^3).

Variety 'OP-1' showed an increasing trend in total bacterial count with increase in storage time (upto 6 months storage). A significant ($p<0.05$) increase in total bacterial count was observed after 3 months and 6 months storage at room temperature and at refrigerated temperature only after six months of storage. Significant differences were also observed in between room and refrigerated temperature, both after 3 months and 6 months storage.

A similar increasing trend was observed in total bacterial count with increase in storage time in varieties 'K.Sutlej' and 'K.Ashoka'. Significant differences were also observed in total bacterial count, both after 3 months and 6 months storage at room and refrigerated

Table 4.4: Microbial load* of potato flour (per gram of sample)

Variety	Fresh	3 months storage		6 months storage		Mean	SEm	C.D.(5%)
		Room Temp.	Refrigerated Temp.	Room Temp.	Refrigerated Temp.			
OP-1								
Total bacterial count	$1.65x10^3$ X •	$1.71x10^3$ •	$1.67x10^3$	$1.82x10^3$ •	$1.70x10^3$ •	$1.71x10^3$	8.13	30.80
Coliform count	ND	ND	ND	ND	ND			
K.Sutlej								
Total bacterial count	$1.76x10^3$ •	$1.82x10^3$ •	$1.79x10^3$ •	$1.90x10^3$ •	$1.84x10^3$ •	$1.82x10^3$	7.46	23.50
Coliform count	ND	ND	ND	ND	ND			
K.Ashoka								
Total bacterial count	$1.74x10^3$ •	$1.85x10^3$ •	$1.81x10^3$ •	$1.91x10^3$ •	$1.86x10^3$	$1.83x10^3$	5.78	18.21
Coliform count	ND	ND	ND	ND	ND			
Mean	$1.72x10^3$	$1.79x10^3$	$1.76x10^3$	$1.88x10^3$	$1.80x10^3$			
SEm	6.38	7.46	7.23	7.82	7.63			
C.D.(5%)	22.06	25.77	23.45	29.44	27.21			

*All values are average of triplicate on dry weight basis

ND- Not detectable (Total number of colonies per count was less than 30)

X -Significant at varietal level

• -Significant at condition level

temperature and also in between room and refrigerated temperature, both after 3 months and 6 months storage.

The total bacterial count of potato flours ($1.65 \times 10^3 - 1.91 \times 10^3$/g), though increased significantly over storage, but it was quite less than the count of ISI specification (IS : 7463 : 1988) for wheat flour which specifies the total bacterial count as 100,000 per g (max).

On the other hand, no coliforms could be detected in potato flours of the varieties 'OP-1', 'K-Sutlej' and 'K.Ashoka' in fresh flours as well as during the entire period of storage.

4.5. Sensory evaluation of potato flour incorporated food products

Three different products, namely biscuit, idli and sev were formulated and evaluated for various sensory quality attributes such as appearance, colour, flavour, texture, taste and overall acceptability (Appendix II). The effect of incorporation of fresh potato flour made from three varieties ('OP- 1', 'K.Sutlej' and 'K.Ashoka') and storage at two different conditions (1. Stored for six months at room temperature and 2. Stored for six months at refrigerated temperature) was studied for the sensory characteristics of the above mentioned products. The results obtained by applying analysis of variance (ANOVA), three factor, are presented and discussed here.

4.5.1. Biscuit

The three factor analysis of variance data for different sensory characteristics namely-appearance, colour, flavour, texture, taste and overall acceptability is given in Table 4.5.1. An insight of ANOVA showed that significant differences ($p<0.05$) existed due to different potato varieties in all the characteristics. Similarly, significant variations ($p<0.01$) existed due to different proportions (levels) of potato flour used for all the sensory characters. However, storage has affected only the colour and taste significantly ($p<0.05$).

4.5.1.1. Overall one way comparison of mean values for main factors

The mean values for different sensory characteristics within three main factor viz., varieties, storage conditions and proportions of potato flour used are presented on Table 4.5.2.

Varieties

Results indicated that of the three potato varieties, variety 'OP-1' and variety 'K.Ashoka' showed their superiority in significant fashion over variety 'K.Sutlej' for appearance of biscuits, although the sensory scores of all the three were judged as fair. Varieties 'OP-1' and 'K.Sutlej' were found significantly different (rated as good) from variety 'K.Ashoka' (rated as fair) for colour of the biscuits. Significant

Table 4.5.1: Analysis of variance (three factor) for various characters of biscuit

Source of variation	Degree of Freedom	Mean Sum of Squares					
		Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
Replication	9	1.443	1.397	3.409	3.131	1.414	0.903
Variety (Factor V)	2	8.036**	11.658**	13.328**	8.897**	3.301**	3.250*
Storage condition (Factor S)	2	1.024	3.992*	2.042	2.064	3.980*	2.211
Proportion (Factor P)	5	131.306**	77.527**	102.937**	68.058**	104.288**	86.450**
Interaction of V&S (V′ S)	4	0.103	0.578	0.266	0.137	1.153	0.112
Interaction of V&P (V′ P)	10	0.104	0.056	0.477	0.107	0.241	0.168
Interaction of S&P (S′ P)	10	0.463	0.156	0.716	0.086	0.910	0.135
Interaction of V,S&P (V′ S′ P)	20	0.181	0.144	0.105	0.119	0.266	0.101
Error	477	0.760	0.858	1.116	0.780	0.883	1.070

*, ** significant at 5% and 1% level, respectively

Table 4.5.2: Biscuit: Table of mean values for main factors viz., varieties (V) storage condition (S) and proportion of potato flour (P)

Characters	Variety			C.D at 5%	Storage condition			C.D. at 5%	Proportion						C.D. at 5%
	V_1	V_2	V_3		S_0	S_1	S_2		P_0	P_1	P_2	P_3	P_4	P_5	
1. Appearance	6.758	6.341	6.611	0.180	6.611	6.583	6.516	0.180	7.772	7.627	7.555	5.844	5.488	5.133	0.254
2. Colour	7.102	7.127	6.675	0.191	7.086	6.936	6.883	0.191	7.888	7.788	7.705	6.450	6.155	5.822	0.270
3. Flavour	5.822	5.511	6.052	0.218	5.797	5.805	5.778	0.218	6.822	6.722	6.650	5.299	4.822	4.455	0.308
4. Texture	5.644	5.250	5.269	0.182	5.491	5.394	5.277	0.182	6.244	6.155	6066	4.966	4.605	4.288	0.258
5. Taste	6.264	6.016	6.044	0.194	6.216	6.191	5.916	0.194	7.122	7.038	6.961	5.738	5.105	4.683	0.274
6. Overall acceptability	6.171	5.938	5.955	0.213	6.022	6.024	6.019	0.213	6.972	6.849	6.810	5.633	5.049	4.794	0.302

V_1 = OP-1
V_2 = Kufri Sutlej
V_3 = Kufri Ashoka

S_0 = Fresh flour
S_1 = Room Temperature (6 months stored)
S_2 = Refrigerated temperature (6 months stored)

P_0 = 0 % potato flour (control)
P_1 = 10 % potato flour
P_2 = 20 % potato flour
P_3 = 30 % potato flour
P_4 = 40 % potato flour
P_5 = 50 % potato flour

difference in flavour of biscuits for all the three varieties was observed at $p<0.05$, however the scores were in the same range i.e. all read as fair. Variety 'OP-1' differed significantly ($p<0.05$) from 'K.Sutlej' and 'K.Ashoka' for texture, taste and overall acceptability and was rated higher than 'K.Sutlej' and 'K.Ashoka'.

Storage Conditions

It is inferred from the Table 4.5.2. that slight but significant differences ($p<0.05$) occurred between colour, texture and taste of the biscuits made from the fresh flour (S_0) and those made from the flour stored at refrigerated temperature for six months (S_2). Colour of the fresh flour incorporated biscuits was rated as good and colour of the biscuits prepared from stored flour samples was rated as fair. There was no difference in the rating for texture and taste, all the biscuits were rated as fair.

Proportions

From the results described in Table 4.5.3, it was revealed that a declining trend of acceptability was observed in correspondence to the increasing levels or proportions of potato flour used for all the sensory characters. Control i.e. proportion P_0 (0 per cent potato flour) showed highest score for all the characters, however scores at P_1 (10 per cent potato flour) and P_2 (20 per cent potato flour) levels were found at par with control for all the sensory characteristics. It was observed that till

F	Potato flour incorporated biscuits

G	Potato flour incorporated sev

P_2 levels there was no significant difference observed in acceptability of the product and all the three levels had similar sensory scores, being judged as good for the attributes appearance, taste and colour and as fair for flavour, texture and overall acceptability. Biscuits prepared from the proportions P_3 (30 per cent potato flour), P_4 (40 per cent potato flour) and P_5 (50 per cent potato flour) showed an inferior significant difference from P_0 , P_1 and P_2 for all the sensory characteristics.

4.5.2. Sev

The three factor analysis of variance data for different sensory characteristics namely –appearance, colour, flavour, texture taste and overall acceptability is presented in Table 4.5.3. ANOVA revealed that significant differences ($p<0.05$) existed in varieties for texture and overall acceptability of sev. Similarly, storage conditions showed significant differences ($p<0.05$) for colour and flavour. Significant variations also existed in proportions for all the characters studied.

4.5.2.1. Overall one way comparison of mean values of sensory characteristics for main factors.

The mean value for different sensory characteristics along with their critical differences for three main factors viz.-varieties, storage

Table 4.5.3: Analysis of variance (3 factor) for various characters of Sev

Source of Variation	Degree of Freedom	Mean sum of squares					
		Appearance	Colour	Flavour	Texture	Taste	Overall Acceptability
Replication	9	2.800	3.552	0.851	0.912	0.843	4.246
Variety (Factor V)	2	2.083	2.683	2.808	4.131*	2.083	3.401*
Storage condition (Factor S)	2	2.085	3.815*	4.494*	2.344	2.016	2.018
Proportion (Factor P)	6	95.412**	105.997**	44.656**	78.044**	111.848**	55.126**
Interaction of V&S (VxS)	4	0.153	0.097	0.100	0.217	0.271	0.104
Interaction of V&P (VxP)	12	0.068	0.026	0.086	0.034	0.036	0.019
Interaction of S&P (SxP)	12	0.118	0.135	0.170	0.102	0.138	0.067
Interaction of V,S & P (VxSxP)	24	0.083	0.128	0.146	0.066	0.059	0.062
Error	558	0.712	0.734	0.964	0.925	0.659	0.656

*, ** significant at 5% and 1% level, respectively

conditions and proportions of potato flour used in sev preparation has been shown in Table 4.5.4..

Varieties

Results showed that variety 'OP-1' differed significantly from 'K.Sutlej' and 'K.Ashoka' for texture and overall acceptability and scored higher than 'K.Sutlej' and 'K.Ashoka', although all the three varieties were rated as fair on the scoring scale for all the characteristics.

Storage Conditions

Regarding storage conditions, sev prepared from fresh potato flour (S_0) showed its significant superiority over the sev made from potato flour stored at S_1 (6 months stored at room temperature) and S_2 (6 months stored at refrigerated temperature) storage conditions for colour and flavour, However, all the samples were rated as fair for these two sensory attributes.

Proportions

The results revealed that significant differences were observed in all the sensory characteristics of sev, above 40 per cent level of potato flour incorporation, from the control (P_0). However, upto 40 per cent (P_4) level of potato flour in corporation, all the sev samples were rated between good and fair for all the sensory characteristics and also did not show any significant difference among the characteristics .

Table 4.5.4: Sev: Table of mean values for main factors viz., varieties(V), storage condition (S) and proportion of potato flour (P)

Characters	Variety			C.D. (5%)	Storage condition			C.D. (5%)	Proportion							C.D. (5%
	V_1	V_2	V3		S_0	S_1	S_2		P_0	P_1	P_2	P_3	P_4	P_5	P_6	
1.Appearance	6.616	6.619	6.652	0.161	6.609	6,650	6.628	0.161	7.200	7.188	7.122	7.138	7.105	6.216	4.433	0.2
2.Colour	6.526	6.514	6.540	0.163	6.636	6.476	6.469	0.163	7.084	7.067	7.089	7.094	7.106	5.961	4.289	0.2
3.Flavour	6.159	6.300	6.255	0.187	6.464	6.107	6.143	0.187	6.539	6.667	6.667	6.522	6.555	5.661	5.056	0.2
4.Texture	6.985	6.011	6.035	0.184	6.057	5.980	5.995	0.184	6.450	6.555	6.522	6.522	6.594	5.216	4.216	0.2
5.Taste	6.588	6.559	6.597	0.155	6.585	6.571	6.588	0.155	7.083	7.172	7.172	7.188	7.233	5.944	4.277	0.2
6.Overall acceptability	6.809	6.619	6.719	0.104	6.702	6.712	6.733	0.154	7.106	7.117	7.161	7.200	7.117	6.105	5.206	0.2

V_1 = OP-1
V_2 = K.Sutlej
V_3 = K.Ashoka

S_0 = Fresh flour
S_1 = Room Temperature (6 months stored)
S_2 = Refrigerated Temperature (6 months stored)

P_0 = 0% potato flour
P_1 = 10% potato flour
P_2 = 20% potato flour
P_3 = 30% potato flour
P_4 = 40% potato flour
P_5 = 50% potato flour
P_6 = 100% potato flour

4.5.3 Idli

The three factor analysis of variance data for different sensory characteristics namely appearance, colour, flavour, texture, taste and overall acceptability is presented in Table 4.5.5. Significant differences ($p<0.05$) existed due to different potato varieties in appearance and overall acceptability. Storage has only affected the colour of idli significantly ($p<0.05$). Significant variations ($p<0.01$) were observed due to proportions for all the sensory characteristics.

4.5.3.1 Overall one way comparison of mean values of sensory characteristics for main factors

The average values for all the sensory characteristics within three main factors i.e. varieties, storage conditions and proportions of potato flour used in idli preparation are presented in Table 4.5.6

Varieties

Results revealed that among the three potato varieties, variety 'OP-1' showed highest scores for appearance and overall acceptability of idli, that was significantly higher than the average values obtained for varieties 'K.Sutlej' and variety 'K-Ashoka'.

Storage Conditions

Idli prepared from the potato flour stored at two storage condition i.e. S_1 (stored for six months at room temperature) and S_2 (stored for six months at refrigerated temperature), did not show any significant difference with each other, as well as with the fresh flour

Table 4.5.5: Analysis of variance (3 factor) for various characters of idli

Source of Variation	Degree of Freedom	Mean sum of squares					
		Appearance	Colour	Flavour	Texture	Taste	Overall Acceptability
Replication	9	2.445	0.437	1.351	2.492	1.395	2.373
Variety (Factor V)	2	4.220*	2.529	2.209	2.150	2.044	4.342*
Storage condition (Factor S)	2	2.356	3.704*	2.104	2.105	2.167	2.046
Proportion (Factor P)	5	74.395**	102.090**	82.273**	129.182**	91.809**	66.157**
Interaction of V&S (VxS)	4	0.158	0.083	0.322	0.696	0.053	0.064
Interaction of V&P (VxP)	10	0.420	0.039	0.452	0.014	0.068	0.027
Interaction of S&P (SxP)	10	0.287	0.102	0.311	0.098	0.142	0.067
Interaction of V,S & P (VxSxP)	20	0.184	0.533	0.186	0.057	0.050	0.131
Error	477	0.991	0.820	1.017	0.974	0.712	0.673

*, ** significant at 5% and 1% level, respectively

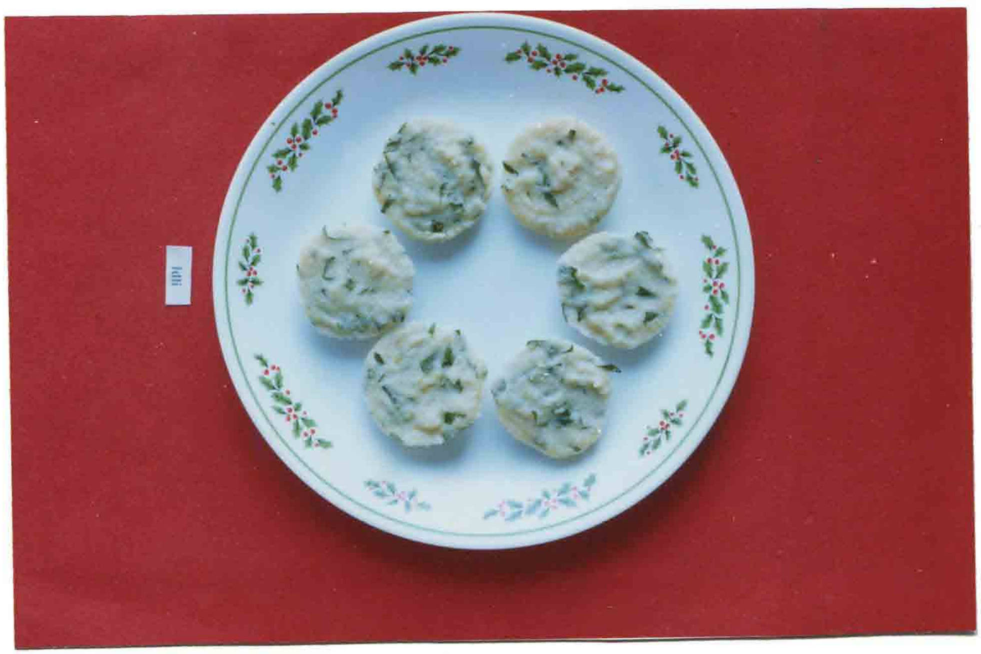
Table 4.5.6: Idli: Table of mean values for main factors viz., varieties(V), storage condition (S) and proportion of potato flour (P)

Characters	Variety			C.D.	Storage condition			C.D.	Proportion						C.D.
	V_1	V_2	V3	(5%)	S_0	S_1	S_2	(5%)	P_0	P_1	P_2	P_3	P_4	P_5	(5%)
1.Appearance	6.302	6.066	6.042	0.205	6.139	6.142	6.131	0.205	6.967	6.883	6.839	5.915	5.225	4.961	0.290
2.Colour	6.641	6.750	6.691	0.187	6.766	6.658	6.658	0.102	7.672	7.605	7.533	6.322	5.883	5.150	0.265
3.Flavour	5.975	5.911	5.963	0.208	5.977	5.936	5.936	0.208	6.777	6.822	6.705	5.677	5.077	4.638	0.294
4.Texture	5.758	5.711	5.763	0.203	5.761	5.755	5.716	0.203	6.844	6.794	6.705	5.316	4.683	4.122	0.288
5.Taste	6.313	6.305	6.336	0.174	6.336	6.336	6.283	0.174	7.266	7.200	7.105	5.950	5.461	4.927	0.246
6.Overall acceptability	6.511	6.278	6.272	0.169	6.367	6.366	6.358	0.169	7.139	7.067	7.049	6.061	5.644	5.161	0.239

V_1 = OP-1
V_2 = K.Sutlej
V_3 = K.Ashoka

S_0 = Fresh flour
S_1 = Room Temperature (6 months stored)
S_2 = Refrigetaed Temperature (6 months stored)

P_0 = 0% potato flour
P_1 = 10% potato flour
P_2 = 20% potato flour
P_3 = 30% potato flour
P_4 = 40% potato flour
P_5 = 50% potato flour



H	Potato flour incorporated idli

(S_0) idli with respect to all the sensory characteristics except for colour. The colour of the fresh flour idli was rated highest and was statistically different ($p<0.05$) from S_1 and S_2 storage conditions, however, all were rated as fair for colour.

Proportions

The results revealed that there were significant differences in all the characteristics at or above 30 per cent level of incorporation of potato flour from control (P_0) in idli preparation, thereby showing lower scores for all the characteristics at 30 per cent (P_3) or above levels. Upto 20 per cent (P_2) level of incorporation the sensory characteristics did not differ and also did not affect the acceptability of the product.

4.6 Effect of potato flour incorporation on water requirement of different food products

The effect of incorporation of different levels of potato flour (fresh and those stored at room and refrigerated temperature for 6 months) made from three varieties ('OP-1', 'K.Sutlej' and 'K.Ashoka') on the water requirement of dough / batter of biscuits, sev and idli were studied. The results so obtained are presented and described here.

4.6.1. Biscuit: Water requirement of dough (ml/100g flour) and baking time:

The results obtained on water requirement of dough and baking time of biscuits made from fresh flour and stored flours (6 months stored at room and refrigerated conditions) are presented in Table

4.6.1. As evident from the results, the amount of water needed for preparation of biscuits from fresh flour ('OP-1'), increased from 23 ml to 40 ml, with the increase in level of potato flour from zero percent (control) to 50 percent. Similarly, for the biscuits prepared from the flours stored at room temperature (6 months) and refrigerated temperature (6 months), the water requirement increased with the increase in level of potato flour incorporation i.e. from 0 to 50 per cent. For the other two varieties i.e. 'K.Sutlej' and 'K.Ashoka', similar trend of increase in water requirements with increase in level of potato flour, was also observed both for fresh flour as well as stored flours. This increase in water requirement may be attributed to high water absorption capacity of potato flour in comparision to wheat flour. The high water absorption capacity of potato flour is due to damaged or free starch (**Purves and Scrively, 1975**).

The baking time for the biscuits prepared from the flour of fresh and stored conditions for all the three varieties decreased from 20 minutes to 8 minutes with increase in level of potato flour incorporation from 0 to 50 per cent. The decrease in baking time can be explained on the basis of decreasing dry matter content with increase in water requirement by the dough.

From the results (Table 4.6.1), it was observed that among all the 3 varieties, 'OP-1' had the maximum water requirement (with maximum water absorption capacity) for dough preparation of

Table 4.6.1: Water requirement of dough and baking time of biscuits prepared using different levels of potato flour (100g dry ingredient)

Level of potato flour incorporation / Variety	Fresh						Stored at room temp. for 6 months						Stored at refrigerated temp. for 6 months					
	0	10	20	30	40	50	0	10	20	30	40	50	0	10	20	30	40	50
OP-1																		
Water added (ml)	23	25	28	32	35	40	23	24	25	29	33	37	23	25	27	30	34	38
Baking time (min.)	20	18	15	12	10	9	20	19	17	15	12	10	20	18	16	13	10	8
K.Sutlej																		
Water added (ml)	23	23.5	25	30	33	38	23	23.5	24.5	27	30	35	23	24	25	28	32	37
Baking time(min.)	20	17	15	11	10	9	20	18	16	14	12	10	20	17	15	13	11	9
K.Ashoka																		
Water added (ml)	23	23.5	24	29	31	36	23	24	24.5	26	29	33	23	23.5	24	27	30	36
Baking time (min.)	20	17	16	12	11	10	20	18	16	14	11	10	20	17	15	12	10	9

0 to 50 = per cent of potato flour incorporation

biscuits, as against the other two varieties, for the fresh as well as stored flours.

4.6.2. Sev : Water requirement of dough (ml/100g flour)

The results obtained on water requirement of dough for sev prepared from fresh flour and the flour stored at room and refrigerated temperature for six months from 3 different potato varieties are presented in Table 4.6.2. As observed, the amount of water required for sev preparation from fresh flours as well as stored flours of all the three varieties increased with increase in level of potato flour incorporation from 0 to 50 pre cent as well as for 100 per cent. Highest amount of water was added to 100 per cent potato flour, which may be attributed to the high free starch content of potato flour.

On comparing the water requirement by flour of all 3 varieties, it was observed that variety 'OP-1' (with maximum water absorption capacity had the maximum water requirement for dough preparation of sev, as compared to other two varieties for all the conditions of flour. This increase may be attributed to the free starch present in flour, which causes increase in water absorption **(Purves and Scrively, 1975)**

Table 4.6.2: Water requirement of dough for preparation of sev using different levels of potato flour (100g dry ingredient)

Level of potato flour incorporation / Variety	Fresh							Stored at room temp. for 6 months							Stored at refrigerated temp. for 6 months						
	0	10	20	30	40	50	100	0	10	20	30	40	50	100	0	10	20	30	40	50	100
OP-1 Water added (ml)	48	50	53	56	64	72	85	48	49	51	55	62	70	84	48	49	52	55	63	70	84
K.Sutlej Water added (ml)	48	50	52	55	62	70	84	48	49	50	54	61	71	83	48	50	51	54	61	69	83
K.Ashoka Water added (ml)	48	50	52	54	61	70	82	48	50	51	53	60	69	81	48	49	51	53	60	68	81

0 to 100 = per cent of potato flour incorporation

4.6.3. Idli: Water requirement of batter (ml/100g flour)

The amount of water required by all the three flours (fresh and stored at room and refrigerated temperature for six months) for the batter of idli preparation (Table 4.6.3.) increased with the increase in level of potato flour from 0 to 50 per cent. The amount of water added ranged from 50 to 220 ml/100g flour, as the level of potato flour incorporation increased from 0 to 50 per cent. Varietal differences in water requirement were also observed, indicating the highest water requirements of potato flour for variety 'OP-1' in all the conditions.

4.7 Nutritional value of potato flour incorporated food products

The food products – biscuit, sev and idli, with highest level of potato flour (fresh, variety 'OP-1') incorporation, which were stastically similar to the control (0 per cent potato flour)in sensory characteristics were subjected to nutrient analysis (moisture, protein, fat and total starch) along with control samples.

Biscuits prepared from the fresh potato flour of variety 'OP-1' with 20 per cent level of potato flour were adjudged to be the best accepted ones (as observed through the sensory scores) and thus were compared with control biscuit samples. The composition of biscuits as presented in Table 4.7.1. clearly shows that no significant differences

Table 4.6.3: Water requirement of batter for preparation of idli using different levels of potato flour (100g dry ingredient)

Level of potato flour incorporation / Variety	Fresh						Stored at room temp. for 6 months						Stored at refrigerated temp. for 6 months					
	0	10	20	30	40	50	0	10	20	30	40	50	0	10	20	30	40	50
OP-1 Water added (ml)	50	85	138	143	160	220	50	84	136	141	158	218	50	85	137	143	159	219
K.Sutlej Water added (ml)	50	83	135	142	158	217	50	82	133	140	156	214	50	83	134	141	158	216
K.Ashoka Water added (ml)	50	82	135	141	156	216	50	81	134	139	154	214	50	82	134	139	153	214

0 to 50 = per cent of potato flour incorporation

were observed in nutritional value of biscuits of potato flour when compared with that of control.

Sev prepared from the fresh potato flour of variety 'OP-1' with 40 per cent level of potato flour incorporation were judged to be best . The composition of 40 per cent potato flour sev did not differ significantly than the sev made from control as shown in Table 4.7.2.

Similarly for idli, prepared from fresh potato flour of variety 'OP-1' with 20 per cent level of potato flour incorporation was adjudged to be the best, but no significant differences were observed in the nutritional characteristics as presented in Table 4.7.3.

Table 4.7.1: Nutritional composition (dry weight basis) of potato flour incorporated biscuits

Product	Moisture (%)	Protein (%)	Fat (%)	Total starch (%)
A	2.26	5.93	15.78	37.69
B	2.38	7.61	15.87	39.89
tcal	1.333	1.226	1.286	1.224
t_{tab}	4.303			

A: Wheat flour : Potato flour (100:00)
B: Wheat flour : Potato flour (80:20)

Table 4.7.2: Nutritional composition (dry weight basis) of potato flour incorporated sev

Product	Moisture (%)	Protein (%)	Fat (%)	Total starch (%)
A	3.97	10.57	23.83	42.54
B	4.83	11.93	26.37	45.92
tcal	1.229	1.225	0.340	1.223
t_{tab}	4.303			

A: Bengal gram flour : Potato flour (100:00)
B: Bengal gram flour : Potato flour (60:40)

Table 4.7.3: Nutritional composition (dry weight basis) of potato flour incorporated idli

Product	Moisture (%)	Protein (%)	Fat (%)	Total starch (%)
A	37.54	5.93	0.68	35.24
B	39.67	6.50	0.61	36.90
tcal	1.224	1.213	1.167	1.221
t_{tab}	4.303			

A: Suji : Potato flour (100:00)
B: Suji : Potato flour (80:20)

Summary and Conclusion

5. SUMMARY AND CONCLUSION

The present investigation was undertaken with a view to study the physico-chemical characteristics, nutritional value and microbial load of potato flour. Three different varieties viz. 'OP-1', 'K.Sutlej' and 'K.Ashoka' were selected for the study. The potatoes of each variety were processed into flour using simple technology by boiling potatoes till done, peeling, grating and drying at 55^0C for 24 hours and finally grinding to flour.

The effect of storage on potato flour i.e. its physico-chemical characteristics, nutrition value and microbial load was studies after 3 and 6 months storage, both at room and refrigerated temperature.

Different food products viz. biscuit, sev and idli were prepared using different proportions of potato flour and these were evaluated for various sensory attributes. The product with the highest accepted level in each of the three variations was studied for nutritional value.

The results of the present investigation are summarized as follows:

1. Among the boiling characteristics of the three potato varieties, colour varied from yellow ('OP-1') to creamy white ('K.Sutlej') and creamy yellow ('K. Ashoka'); no disintegration was observed; consistency ranged from slightly soft ('K. Sutlej' and 'K.Ashoka') to soft ('OP-1'); mealiness was found only for variety 'OP-1', slight dryness was observed for variety 'OP-1' while moist conditions were recorded for varieties 'K.Sutlej' and 'K.Ashoka' and for structure, all the three varieties were rated as fine.

2. A close texture was observed for 'OP-1' and varieties 'K.Sutlej' and 'K.Ashoka' showed a waxy texture.

3. Yield recovery of potato flour was recorded highest (16. 17 per cent) for variety 'K.Sutlej', followed by varieties 'OP-1' (15.45 per cent) and 'K. Ashoka' (14.14 per cent).

4. The colour of the potato flour from three different varieties differed in their hue and value, however, all were rated as pale yellow, based on Munsell soil colour chart (1954). Storage had no effect on colour of potato flour.

5. The water absorption capacity of variety 'OP-1' (346.67 per cent) differed significantly ($p<0.05$) from the varieties 'K.Sutlej' (336.67 per cent) and 'K.Ashoka' (286.67 per cent). Varieties 'OP-1' and 'K. Ashoka' showed a significant decrease in water absorption capacity after 3 and 6 months at room temperature and after 6 months at refrigerated temperature also. 'K.Sutlej' also showed a similar trend except between room and refrigerated temperature occurred at 3 months storage.

6. The moisture sorption isotherm of fresh as well as stored potato flours of all the three varieties showed that potato flour can be stored safely up to 50 per cent relative humidity without affecting its quality.

7. Particle size index of variety 'OP-1' (36.07) differed significantly ($p<0.05$) with the varieties 'K. Sutlej' (34.91) and 'K.Ashoka' (34.84), while later two varieties did not show any significant difference with each other. Storage had no effect on the particle size index of the flours.

8. Water absorption capacity of potato flours showed a significant and positive correlation with particle size index (r =0.63) and starch content (r =0. 516).

9. No varietal differences were observed for moisture content in potato flours. The moisture content of potato flour of varieties 'OP-1', 'K.Sutlej' and 'K.Ashoka' were observed as 8.08, 8.10 and 8.48 per cent, respectively. Varieties 'OP-1' and 'K.Sutlej' showed a significant increase (p<0. 05) in moisture content at 3 months and 6 months storage at room and refrigerated temperature, whereas variety 'K.Ashoka' exhibited significant differences at room temperature only, at both the storage period.

10. The protein content of varieties 'OP-1' (10. 48 per cent) and 'K. Sutlej' (10. 33 per cent) differed significantly (p<0. 05) from variety 'K.Ashoka' (9. 24 per cent). Storage of flours upto 6 months at room and refrigerated temperature had no significant effect on the protein content.

11. The total ash content of variety 'OP-1' (3. 09 per cent) did not show any significant (p<0.05) difference with that of variety 'K. Sutlej' (2.83 per cent), but differed significantly with that of 'K. Ashoka' (2. 56 per cent). However, no significant effect of storage was observed for the total ash content.

12. The highest starch content (78. 04g/100g) was observed in variety 'OP-1' that differed significantly (p<0.05) from that of varieties 'K.Sutlej' (76. 39g/100g) and 'K.Ashoka' (75. 57g/100g). No significant change in the starch content was observed during storage.

13. Calcium content of variety 'OP-1' (21.76mg/100g) showed significant (p<0.05) differences with varieties 'K.Sutlej'

(18.14mg/100g) and 'K.Ashoka' (18.21mg/100g). However, phosphorus content of variety 'OP-1' (188.57mg/100g) did not show any significant difference with variety 'K.Sutlej' (177.73 mg/100g) but differed significantly ($p<0.05$) with that of 'K.Ashoka' (171.19mg/100g). On the other hand, non significant differences were observed in the total iron content of varieties 'OP-1' (3.93mg/100g) and 'K.Ashoka' (3.89 mg/100g) but 'OP-1' differed significantly from that of 'K.Sutlej' (3.63mg/100g). Storage had no effect on calcium, phosphorus and iron contents.

14. The ascorbic acid content of varieties 'OP-1' (8.70mg/100g) and 'K.Ashoka' (7.12mg/100g) differed significantly ($p<0.05$) from variety 'K.Sutlej' (6.96mg/100g). A significant ($p<0.05$) decrease in the ascorbic acid content of flours was observed in all the three varieties at different durations and conditions.

15. *In-vitro* protein digestibility of varieties 'OP-1' (77.00 per cent) and 'K.Sutlej' (75.89 per cent) showed non-significant differences in *in-vitro* protein digestibility, whereas both differed significantly from 'K.Ashoka' (72.85 per cent). *In-vitro* protein digestibility did not change with storage upto six months in all the conditions.

16. The total dietary fiber content of varieties 'OP-1' (6.60g/100g) and 'K.Ashoka' (6.47g/100g) showed similar dietary fiber content with no significant differences, however, variety 'OP-1' differed significantly ($p<0.05$) from that of 'K.Sutlej' (6.25g/100g). No significant effect of storage on dietary fiber content of all the flours were observed.

17. Lowest total bacterial count was recorded in variety 'OP-1' ($1.65X10^3$) which was significantly ($p<0.05$) lower from the other two varieties 'K. Sutlej' ($1.76x10^3$) and 'K.Ashoka' ($1.74X10^3$).

Total bacterial count increased significantly during storage for all the flours, with significantly higher values at 6 months storage at room temperature, but this was within the limits prescribed by ISI specification (100,000/g, max.). However, no coliforms were detected in any of the flours.

18. Statistical analysis of the sensory evaluation of the food products (biscuit, sev and idli) showed that biscuit and idli prepared from 20 per cent potato flour incorporation and sev prepared from 40 per cent potato flour incorporation were similar to the control and were accepted.

19. The water requirement for each of the products (biscuit, sev and idli) increased with increase in level of potato flour. Maximum water requirement was recorded for the variety 'OP-1' for the preparation of dough of biscuits and sev and batter of idli.

20. The nutritional value (moisture, protein, fat and starch) of potato flour incorporated food product viz. biscuit, sev and idli was found to be similar to the control samples.

Based on the present investigation, it would be concluded and recommended that :

- Potato flour can be utilized as an important processed potato product both at household and commercial level.
- Moreover, potato flour can be stored without any adverse changes in physico-chemical characteristics, nutritional value and microbial load uptill six months, both at room and refrigerated conditions with proper packaging (double polythene bags) in air tight plastic containers.

Literature cited

LITERATURE CITED

A.O.A.C. 1975. Official Methods of Analysis of the Association of Official Analytical Chemists. 12th ed. Washington D.C., U.S.A.

Akeson,Walter,R. and Stahmann, Mark, A.1964. A pepsin pancreatin digest index of protein quality evaluation. *J. Nutr.* 83:257-261.

Akubor,P.L. 1997. Proximate composition and selected functinal properties of African bread fruit and sweet potato flour blends. *Plant Foods for Human Nutrition.* 51(1):53-60.

Amerine, M.A.; Pangborn, R.M. and Roseller, E.B.1973. Principles of sensory evaluation of food. New York and London. Academic Press.

Amla,B.L. and Shankar, J.V.1975. Post harvest technology of food grains, fruits, vegetables and other tubers. *Fd. Technol. in Australia.* 27(11):455-468.

Anand,J.C.; Maini, S.B. and Diwan, B. 1982. A simple way to preserve potato for chips making.*J. Fd. Sci. Technol.* 19:267.

Anderson,J.W. and Bridges, S.R. 1988. Dietary fiber content of selected foods.*Am.J. Clin. Nutr.* 47(3):440-447.

Anderson,J.W.; Smith, B.M.and Gustafson, N.J. 1994. Health benefits and practical aspects of high-fiber diets. *Am.J. Clin. Nutr.*, 59(5S): 1242S-1275S.

APHA.1976. Compendium of methods for the microbiological examination of foods. *In:* Speck, M.L. American Public Health Association. New York. U.S.A. 107-119.

Asp, N.G. and Johansson, C.G. 1981. Techniques for measuring dietary fiber : Principal aims of methods and a comparison of results obtained by different techniques. *In:* James, W.P.T. and Theander, O. The analysis of dietary fiber in food. Marcel Dekker Inc. New York and Basel. 3:173-179.

Augustin, J.; Swanson, B.C.; Pomatto, S.F.; Teitzel, C.; Artz, W.E. and Huang, C.P. 1979. Changes in nutrient composition of dehydrated potato products during commercial processing. *J. Fd. Sci.* 44(1):216-219; 807-809.

Augustin, J.; Toma, R.B.; True, R.H.; Shaw, R.L.; Teitzel, C.; Johnson, S.R. and Orr, R. 1979. Composition of raw and cooked potato peel and flesh : proximate and vitamin composition. *J. Fd. Sci.* 44(3):805-806.

Augustin,J. 1975. Variations in the nutritional composition of fresh potatoes. *J. Fd.Sci.*40:1295-1299.

Augustin,J.; Johnson, S.P.; Teitzel, C.; Toma, R.B.;Shaw, R.L.; True, R.H.; Hogan, J.M. and Deutsch, R.M. 1978. Vitamin composition of freshly harvested and stored potatoes. *J. Fd. Sci.* 43(5):1566-1571.

Augustin,J.; McDole, R.E.; McMaster, C.M.; Painter, C.C. and Sparks,W.C.1975. Ascorbic acid in Russet-Burbank potatoes. *J. Fd. Sci.* 40(2):415-416.

Bajaj, S. 1987. Biotechnology of nutritional improvement of potato. *In*: Bajaj, Y.P.S. Biotechnology in agriculture and forestry. Vol. 3. Springer-verlag. Berlin. Heidelberg : 136-145.

Bansal,M.1986. Physical and chemical characteristics of powders made from different potato varieties. Thesis,M.Sc. G.B. Pant Univ. of Ag. & Tech., Pantnagar.

Baremore, M.A. 1937. Potato mealiness and changes in softness on cooking. *Fd. Research.* 2:377-383.

Barkar, J. 1938. The effect of temperature history on the sensitivity of sugar/starch blanching system in potatoes. Reports of food investigations Board (London): 193-195.

Bascunan, W.J. 1979. Study of the chemical composition, biological quality and acceptability of bread with added potato flour. *Farmacologicas.* 29/30:69-70.

Bedolla, S. and Rooney, L.W. 1984. Characteristics of U.S. and Mexican instant maize flours for tortilla and snack preparation. *Cereal Foods World.* 29(11):732-735.

Beeerh, O.P.; Manan,J.K.; Joshi, G.J. and Berry, S.K. 1988. Effect of climate, variety and post cold storage conditioning of potatoes on quality of potato wafers. *Indian Fd. Packer.* 42(5):53-61.

Beirne, D.O. 1990. Effect of nitrogen fertilization on yield, dry matter content and flouriness of potatoes. *J. Sci. Fd. Agric.* 52(3):351-363.

Beristain, G.C.I.; Vazquez, L.A. and Cortes, G.R. 1990. Use of waste potatoes in the preparation of whole flour for the development of foods for popular consumption. *Archivos Latinoameri Canos de Nutricion.* 40(1):75-85.

Beukama, H.P.and VanderZaag, D.E.1979. Potato improvement : Some factors and facts. International Agricultural Centre, Wageningen. The Netherlands..

Bonchev, N.1965. Alterations in the protein and amino acid content of some foods resulting from heat treatment and the action of enzymes.*Nahrung.* 9:161.

Bretzlofe, C.W. 1970. Some aspects of the cooked potato texture and appearance: Potato Cell size stability during cooking and freezing. *Amer. Potato J.* 47(5): 176-185.

Brody, J. 1969. Pointers on potatoes. *Fd. Engineering.* 41:124-132.

Bunimovitch, M. and Faitelowitz,A. 1936. An improved method of reducing potatoes and other starch – containing vegetables to the form of a dry powder. *British Patent.*457,088.

Burg,P. and Fraile, P. 1995. Vitamin C destruction during the cooking of a potato dish. *Lebensmittel Wissenschaft und Technologie.* 28(5):506-514.

Burton, W.G. 1945. Mashed potato powder. III. The high temperature browning of mashed potato powder. *J. Soc. Chem. Ind.* London. 64:215-218.

Burton, W.G. 1949. Mashed potato powder. IV Deterioration due to oxidative changes. *J. Soc. Chem. Ind.* 68: 149-151.

Burton, W.G. 1966. The potato. 2nd ed. Wageningen. 128-130, 748-761.

Burton, W.G. 1989. The Potato.3rd ed. Longman Scientific and Technical Publication,U.S.A., New York. 1-32, 377-410.

C.I.P. 1984. International Potato Centre. Potatoes for the developing world : A collaborative experience. Lima, IPC.12-14,98.

Central Potato Research Institute. 1980. Annual Report, CPRI. Shimla. 59-60.

Chadha, K.L. 1994. Potato a future food crop of India. *J. Indian Potato Assoc.* 21(1-2):7-20.

Chalom,S.; Elrezzi, E.; Pena, P.; Astiarsaran, I.and Bello,J. 1995. Composition of sulfited potatoes :Comparison with fresh and frozen potatoes. *Plant Food for Human Nutrition.* 47(2):133-138.

Chandrashekara, S. and Shurpalekar, S.R. 1983. Some chemical, pasting, rheological and textural characteristics of composite flours based on wheat and tubers. *J. Fd. Sci. Technol.* 20(6):308-312.

Chandrashekara, S. and Shurpalekar, S.R. 1984 a. On the use of potato and cassava flours in soft dough biscuits. *J. Fd. Sci. Technol.* 21:239-241.

Chandrashekara, S. and Shurpalekar,S.R. 1984 b. On the quality of bread containing differently processed potato. *J.Fd. Sci. Technol.* 21: 234-236.

Chaube, B.B. and Mazza, G. 1983. A non-destructive method for rapid evaluation of boiling quality of potato tubers. *American Potato Journal.* 60(9): 693-698.

Chaudhuri, R.N.R.; Joseph, A.A.; Daniel, V.A.;Rao, M.N.;Swaminathan, M.; Sreenivasan, A. and Subrahmanyan, V. 1963. Effect of cooking, frying, baking and canning on the nutritive value of potato. *Fd. Sci. 2:253.*

Choi, O.J. and Koh, M.S. 1991. The effects of microwave heating on the fatty acid composition of potato flour in storage. *J. Korean Soc. Fd. Nutr.* 20(5):461-466.

Ciecko, Z. 1974. Content of organic and mineral nitrogen in potato tubers. *Zesz-Nauk. Akad.Roln-Tech. Olsztynie. Roin.* 7:199.

Cieslik, E. 1994. The effect of naturally occurring vitamin C in potato tubers on the levels of nitrates and nitrites. Food Chemistry. Elsevier Applied Science Publishers. 49(3):233-235.

Danowska, M. and Barowski, J. 1994. Effects of milk concentrates and faba bean flour on storage stability of dried potatoes. *Acta Academiae Agriculturae Ac. Technicae Olstenensis Technologia Alimentorum.* 27:79-88.

Dreher, M.L. 1987. Handbook of dietary fiber. An Applied Approach. New York and Basel, Marcel Dekker Inc. 468.

Edwards, P.W. and Hoersch, A. 1952. Drying potatoes for food in a direct fired rotary drier. Economic feasibility of the process. *Am. Potato J..* 29:103-112.

Eipeson,W.E. and Bhowmik, S.R. 1992. Indian fruit and vegetable processing industry potential and challenges. *Indian Fd. Packer.* 46(5):7-12.

ElAdawy, N.A. and Attia.1995. Irradiated and stored potato flour as substitute for portion of wheat flour in Shamy bread. *Annals of Agricultural Science.* Moshtohor.33(1):265-278.

Ereifej, K.I.; Shibli, R.A.; Ajlowni, M.M. and Hussein, Altaf.1998. Mineral contents of whole tubers and selected tissues of ten potato cultivars grown in Jordan. *J. Fd. Sci. Technol.* 35(1):55-58.

Eskew, R.K. and Edwards, P.W. 1950. Food and feed from white potatoes. U.S. Dept. Agr. Year Book.177-183.

Ezekiel, R.; Paul, V.; Singh, J. and Shekhawat, G.S.1999. Potato storage in India. *In*: Indian Farming. 49(9):21-25.

Ezekiel, R.; Verma, S.C.; Sukumaran, N.P. and Shekhawat, G.S. 1999. A guide to potato processors in India. Technical Bulletin. No. 48. Central Potato Research Institute. Shimla.1-38.

Fan, T.Y. and Yuch, M.H. 1980. Potato flavour generation – An approach to the flavour improvement of dehydrated potato product. *J. Fd. Sci.*. 45:748-749.

FAO.1998. Production year book. Food and Agriculture Organization of the United Nations. 52(148):83.

Faulks, R.1986. Potato texture. *Nutrition and Food Science*. 12:2-3.

Feustel, I.O.; Handel, C.E. and Juilly, M.E. 1964. Food dehydration. ed. Vol. II. AVI Publishing Company. Westport. Connecticut. 308-398.

Food Digest. 1998. 21(2):64.

Fuller, T.J. and Hughes,J.C. 1984. Factors influencing the relationships between reducing sugars and fry colour of potato tubers of cv. Record. *J. Fd. Technol.* 19:455-467.

Gahlawat, P. and Sehgal,S. 1998. Protein and starch digestibilities and mineral availability of products developed from potato, soy and corn flour. *Plant Foods for Human Nutrition*. 52:151-160.

George, J.and Mahadeviah,M. 1989. Suitability of flexible packaging materials for packaging mango juice. *Indian Fd. Pakcer.* 43(2):57-65.

Gopalan, C.; Rama Sastri, B.V. and Balasubramanian, S.C. 1999. Nutritive value of Indian foods. National Institute of Nutrition. ICMR, Hyderabad.

Gorun, E.G. 1978. Changes in vitamin activity of potatoes during production of quick-frozen fries. *In*: Russian, *Kholod Tekh.* 10:15-17.

Gould, W.A. 1986. Procurement of chipping potatoes. Chipper/Snacker, January. 86-88.

Grewal, J.S. 1993. Potato growth and development in India. "Souvenir" Golden Jubilee (1942-1992) Symposium, Horticultural Research – Changing Scenario, Bangalore (May 24-28) 44-55.

Grewal, S.S. and Uppal, D.S.1989. Effect of dry matter and specific gravity on yield, colour and oil content of potato chips. *Indian Fd. Packer.* 43:17-20.

Gueler, A.and Kolsarici, D. 1995. Effect of attitudes on morphology, physiology, yield and quality characteristics of some potato cultivars grown in different locations. *Turkish Journal of Agriculture and Forestry.* 19(5):383-389.

Haase, N.U. and Plate,J.1996. Quality of potatoes. *Kartoffelbau.* 47(4):138-142.

Hadziyev, D.and Steele, L.1979. Dehydrated mashed potatoes-chemical and biochemical aspects. *Adv. Fd. Res.* 25:55-137.

Hamed, M.G.E.; Hussein, M.F.; Refai, F.Y. and El-Samahy.1973. Preparation and chemical composition of sweet potato flour. *Cereal Chemistry.* 50(2):133-139.

Harrington, W.O.; Olson, R.L.; Weston, W.J. and Belote,M.L.1959. Effects of process variables in potato granule production. *Am. Potato J.* 36:241-254.

Hellendoorn, E.W.; Nordhoff, M.G. and Slagman, J. 1975. Enzymatic determination of the indigestible residue (dietary fiber) content of human food. *J. Sci. Fd. Agri.* 26:1461-1468.

Hodge, J.E.and Osman, E.M. 1976. Carbohydrates. *In*: Fennema, O.R. Principles of food science. Part I. Marcel Dekkar Inc. New York. 792.

Holm, E.T.; Orr, P.H.and Johansen, R.H. 1994. Sensory evaluation as a tool in breeding potatoes for French fries and flakes. *Am. Potato J.* 71:1-14.

Horton, D. and Sawyer, R.L.1985. The potato as a world food crop, with special reference to developing areas. *In:* Paul, M. Li. Potato physiology. London. 2-32.

Hughes, J.C. 1983. Potato production and processing. *Chem. Ind.* 15:598-603.

Hughes, J.C. and Swain, T. 1962a. After cooking blackening in potatoes. II . core experiments *J. Sci. Food Agic.* 13:229-236

Hughes, J.C. and Swain, T. 1962b. After cooking blackening of potatoes III. Examination of interaction of factors by *in vitro* experiments. *J.Sci. Food Agric.* 13:358-63

Hughes, J.C. and Swain, T. 1969. After cooking blackening and the chemistry of Majestic and Ulster Beacon tubers during the growing season. *European Potato Journal.* 12: 256-262

Hughes,J.C.; Faulks, R.M. and Grant, A. 1975. Texture of cooked potatoes. Relationship between compressive strength of cooked dishes and release of pectic substances. *J. Sci. Fd. Ag.* 26(8):731-738.

Hunt, W.H.and Pixton, S.W. 1974. Moisture : Its significance, behaviour and measurement. *In* : Christensen, C.M. Storage of cereal grains and their products. American Association of Cereal Chemists. St. Paul, Minnesota. 11-15.

Ifenkewe, O.P. and Allen, E.J. 1978. Effects of tuber size on dry matter content of tubers during growth of two main crop potato varieties. *Potato Res.* 21(2):105-112.

Ifenkewe, O.P.; Allen, E.J. and Wurr, D.C.E. 1974. Factors affecting the relationship between tuber size and dry matter content. *Am. Potato J.* 51(7):233-242.

Indian Farmer's Digest (IFD). 1999. Food security through diversified means. Published by Director, Communication Centre. G.B. Pant University of Agriculture and Technology. Pantnagar. 32(3):3.

Jadhav,S.; Steele,L. and Hadzlyer, D. 1975. Vitamin C losses during production of dehydrated mashed potatoes. *Lebensmittel-Wissen Schaft-4 Technol.* 8:225.

Johnson, V.A. and Lay, C.L.1974. Genetic improvement of plant protein. *J. Ag. Fd. Chem.* 22:558.

Joshi, M.R.; Srirangarajan, A.N.and Thomas, P. 1990. Effect of gamma irradiation and temperature on sugar and vitamin C changes in five Indian potato cultivars during storage. *Fd Chem.*35(3):209-216.

Kaldy, M.S. 1972. Protein yield of various crops are related to protein value. *Econ. Botany.* 26:142.

Kaldy, M.S. and Markakis, P. 1972. Amino acid composition in selected potato varieties. *J. Fd.Sci.* 37:357.

Karrika,K.J.; Dudgeon, L.T. and Hauck, H.M. 1944. Influence of variety, location, fertilizer and storage on the ascorbic acid content of potatoes grown in New York. *J. Agri. Res.* 68:49-63.

Katara, D.K. 1983. Development of simple processes for manufacturing cubes, flour and starch from culled potatoes. Thesis, M.Sc. G.B. Pant University of Agriculture and Technology, Pantnagar.

Keijbets, M.J.H. and Ebbenhorst,S.G. 1990. Loss of vitamin C (ascorbic acid) during long term cold storage of Dutch table potatoes. *Potato Res.* 33(1):125-130.

Khan, A.; Chauhan, G.S. and Tomar, N.S. 1997. Physico-chemical characteristics of potatoes as a function of cultivar. *Indian Fd. Packer.* 51(4):15-17.

Khan, M.N.; Denosiers, M.C.; Rooney, L.W.; Morgan, R.G. and Sweat, R.E. 1982. Corn tortilla : Evaluation of corn cooking processes.*Cereal Chemistry.* 59:259.

Kirkpatrick, M.; Mountjoy, B.; Albright, L. and Hunze, P. 1951. Cooking quality, specific gravity and reducing sugar content of early crop potatoes. United States Dept. of Agriculture. No. 872.

Kirkpatrick, M.E.; Heinze, P.H.; Craft, C.C.; Mountjoy, B.M. and Flatko, C.E. 1956. French frying quality of potatoes as influenced by cooking methods, storage conditions and specific gravity of tubers.U.S. Dept. of Agriculture. Technical Bulletin. 1142.

Kolbe, H. 1995. Factors influencing the constituents of potatoes. I. Dry matter and starch. *Kartoffelbau.* 46(10):404-411.

Kulge, G.; Kalsbach, R.; Pepperl, I. and Skoppeck, H.P. 1985. Dried potato product and their manufacture. *German Federal Republic Patent.*DR. 3410823 C.

Kulkarni, K.D.; Govinden, N. and Kulkarni, D.N. 1993. Investigations on the production and utilization of dehydrated potato in Mauritius. *Revue Agricole et. Sucriere del I'le Maurice.* 71(2/3):63-73.

Kulkarni, K.D.;Govinden, N.and Kulkarni, O.1996. Production and use of raw potato flour in Mauritian traditional foods. *Food and Nutrition Bulletin.* 17(2):162-168.

Kumar,D.; Gaur, P.C.; Pandey, S.K.; Singh,J. and Singh,S.V. 1999. Effect of storage and reconditioning on recently released Indian potato processing varieties. *J. Indian Potato Assoc.*. 26(1-2):71-73.

Labuza, T.P.1968. Sorption phenomena in foods. *Fd. Technol.* 22(263):15-17.

Lal, S.S.; Govindakrishnan, P.M. and Sharma, R.C. 1999. Agrotechniques for potato production. *In* : *Indian Farming.* 49(9):17-20.

Lal,S.B. 1980. The past twenty and the next twenty years of potato in India.*J. Indian Potato Assoc.* 7(1):1-10.

Leichsenring, J.M.; Norris, L.M. and Pilcher, H.L. 1957. Ascorbic acid contents of potatoes. Effect of storage and of boiling on the ascorbic, dehydroascorbic and diketo gluconic acid contents of potatoes. *Fd. Res.* 22:37-50.

Li, Y.H. and Li, C.F. 1979. Study on the new method of potato peeling and the utilization of potato flour. Food Indusry Research and Development Institute. No. 134, 13.

Lisinska, G. and Leszczynski, W. 1989. Potato science and technology. Elsevier Science Publishers Ltd. Poland.1-13, 136, 233-280, 391.

Markakis, P. 1975. Protein nutritional quality of foods and feeds. Part 2. Marcel Dekkar Inc. New York.

Marwaha, R.S. 1987. Evaluation of some potato cultivars for processing on the basis of thier chemical composition. *J. Indian Potato Assoc.* 14(1&2):9-16.

Marwaha, R.S. 1988. Nutritional composition of commonly cultivated potato varieties grown under short day conditions. *Indian J.Pl. Sci.* 5(1/2):44-51.

Marwaha, R.S. 1997. Processing of potatoes: Current status, need, future potential and suitability of Indian varieties – A critical appraisal. *J. Fd. Sci. Technol.* 34(6): 457-471.

Marwaha, R.S. 1998. Evaluation of Indian and exotic potato cultivars for processing into French fries. *J. Indian Potato Assoc. 25(1&2):61-65.*

Marwaha, R.S. 1999. Chipping quality and related processing characteristics of Indian potato varieties grown under short day conditions. *J. Fd. Sci. Technol.* 36(2):157-159.

Marwaha, R.S. and Kang, G.S. 1994. Evaluation of exotic potato germplasm under short days for processing and yield. *In* : Shekhawat,G.S.; Khurana, S.M.; Paul, M.; Pandey,S.K. and Chandla, V.K. Potato present and future. IndianPotato Association, Shimla.

Marwaha, R.S. and Kumar, Raj. 1987. Relationship between specific gravity and dry matter content of potato tubers. *International Journal of Tropical Agriculture.* 5(3):227-230.

Marwaha, R.S. and Sandhu, S.K. 1999. Processed products from potato. *In : Indian Farming.* 49(9):31-32, 37-38, 41.

Marwaha, R.S.; Devender Kumar and Gaur, P.C. 1998.French fry quality of some advanced potato hybrids. *Indian Fd. Packer.* 52(5):11-15.

Marwaha, R.S.; Kumar, D. and Gaur, P.C. 1999. Studies on advanced potato hybrids for the preparation of French fries. *J. Fd. Sci. Technol.* 36(5):449-452.

Marwaha,R.S. 1988. Nutritional composition of commonly cultivated potato varieties. *Indian J. Nutr. Dietet.* 25:26-31.

Marwaha,R.S. 1996a. Chipping performance of exotic cultivars stored in evaporatively cooled store and at ambient temperature. *Am. Potato J.* 73(8):371-372.

Matz,S.A. 1960. Bakery technology and engineering. The AVI Publishing Company. Connecticut.225.

McBean, D.M.; Joslyn, M.A. and Nury, F.S. 1971. Dehydrated fruits. *In* : Hume, A.C. The biochemistry of fruits and their products. Vol. II. Academic Press. London and New York.

McLaughlin, C.P. and Magee, T.R.A. 1998. The determination of sorption isotherm and the isosteric heats of sorption for potatoes. *J. Fd. Engineering.* 35:267-280.

Mehta, A. and Kaul, H.N. 1988. High temperature storage of potato for processing – a feasibility study. *Plant Foods for Human Nutrition.* 38:263-268.

Mica, B. 1969. Influence of conditions of manuring on the protein content of potatoes. Proceedings of 8th International Congress. 739.

Mica, B.; Blahovex, J.and Vokal, B. 1984. Composition, firmness and darkening of boiled potatoes grown under different fertilization conditions. *Sbornick Utiz Potravinaska Viedy.* 2(3):183-196.

Misra, J.B. 1987. Effect of methods of cooking on vitamin C content of potato tubers. *J. Indian Potato Assoc.* 14(1&2):40-43.

Misra, J.B. and Premchand. 1988. Improvement of chipcolour by removal of colour reactants from potato tuber slices by water washing. *J. Fd. Sci. Technol.* 25:99-100.

Mondy, N.I. and Gosselin, E. 1988. Effect of peeling on total phenols, total glycoalkaloids discolouration and flavour of cooked potatoes. *Journal of Food Sciences.* 53(3):756-759.

Mudambi, S.R. and Rajgopal, M.C.1980. Role of potato in children nutrition. *Indian Fd. Packeri, 34(5):25.*

Mulder, E.G. and Bakema K. 1956. Effect of nitrogen, phosphorus, potassium and magnesium nutrition of potato plants on the content of free amino acids and on the amino composition of the proteins of tubers. *Plant and Soil.* 7:135-166.

Munsell Soil Colour Chart. 1954. Evanston. Illinois, U.S.A. Soil Test Inc.

Musette, M. and Bussiere, G. 1977. New applications for potato pulp and corresponding new product. *French Patent.* 2231-2293

Nagaich, B.B. 1977. Recent technology in potato improvement and production centre. Potato Research Institute. Shimla. 296-303.

Nanda, P. and Khanna, P. 1988. Nutritive value and shelf life of home based potato flour. *Indian J. Nutr. Dietet.* 25:288.

Nelson, Marie.1978. Manufacture and usage of potato flour. 8th Annual Symposium Central States Section, American Association of Cereal Chemists. St. Louis, Missouri. Feb. 17-18.Rogers Brothers Company, Idaho Falls. Idaho.

Noel, W.A. 1922. Manufacture of white potato flour. Chemical Age, 30:381.

Nowotny, F. 1969. Starch. WNT, Warsaw.

Olson, R.L. and Harrington, W.O. 1955. Potato granules, development and technology of manufacture. *Adv. Fd. Res.* 6:231-253.

Olson, R.L.; Harrington, W.O.; Neel, G.H.; Cole, M.W. and Mullins, W.R. 1953. Recent advances in potato granule technology. *Fd. Technol.* 7:177-181.

Oyenuga, V.A. and Fetuga, B.L. 1975. Chemical composition, digestibility and energy values of some varieties of yams, cassava, sweet potatoes and cocoyams for pigs. *Nigerian J. Sci.* 9(1):63-110.

Pant, S. and Kulshreshtha, K. 1994. Frying quality of six varieties of potato. *J. Fd. Sci. Technol.* 31(5):428-429.

Pant, S. and Kulshreshtha, K. 1995. Physical characteristics of potato flour made from six potato varieties. *J. Fd. Sci. Technol.* 32(1):71-73.

Pelletier, O.; Nantel, C.; Leduc, R.; Tremblay, L. and Brassard, R. 1977. Vitamin C in potatoes prepared in different ways. *J. Inst. Can. Sci. Technol. Aliment.* 10:138-142.

Peshin, A. 1998. Evaluation of potato cultivars for processing. *Indian Fd. Packer.* 52(1):22-25.

Petelle, J.; Stoesz, K.D. and Williams, L.R. 1995. Method of making fat free potato chips. *United States Patent.*

Ponnampalam, R. and Mondy, N.I. 1983. Effect of baking and frying on nutritive value of potatoes, nitrogenous constituents. *J. Fd. Sci.* 48:1613.

Porodina, L.V. and Gab, A.A. 1993. Influence of storage method on quality of potatoes. *Tovarovedenie.* 26:35-37.

Potato Marketing Board, London, U.K. 1971. Quality requirements for processing. Potato processing in Great Britain, 1-8.

Pretson, K.R. and Tipples, K.H. 1978. An ultra centrifuge flour absorption method. *Cereal Chemistry.* 55(1):96-101.

Pritchard, M.K. and Adam, L.R. 1994. Relationships between fry colour and sugar concentration in stored Russet Burbank and Shepody potatoes. *Am. Potato J.* 71:59-68.

Pruthi, J.S. 1964. Technology of potato processing. *The Indian Potato Journal.* 6(1): 3-6.

Pruthi, J.S. 1978. Quality control, packaging and storage of dehydrated foods. *Indian Fd. Pakcer.* 32(1):30-40.

Purves, E.R. and Scrively, C.V. 1975. Decreasing the retrograded starch level and increasing the rehydration rate of dehydrated potato granules. *U.S. Patent.* 866-917.

Rai, R.D. 1990. Studies on potato chips, flour and starch making by solar dehydration. *Indian Fd. Packer.* 44(4):9-12.

Ranganna, S. 1994. Handbook of analysis and quality control for fruit and vegetable products. 2nd ed. New Delhi, Tata McGraw-Hill Publishing Company Limited. 27-28, 125-126, 480-485.

Rao, R.N. 1998. Potato – The versatile vegetable. *Nutrition.* 32(4):10-15.

Ravindran, V.; Ravindran, G.; Sivakane San, R. and Rajaguru, S.B. 1995. Biochemical and nutritional assessment of tubers from sixteen cultivars of sweetpotato. *J. Agric. Fd. Chem..* 43(10):2646-2651.

Rendle, T. 1945. The preservation of potatoes for human consumption. *Chem. Ind.* 345-349.

Rennick, R.H.F. 1911. The Narkanda patent potato meal factory. *Agric. J. India.* 6:410-413.

Reust, W.; Winiger, F.A.; Maag, W. and Rek, J. 1993. New Varieties of edible potatoes. Results of principal studies from 1988-1990. *Revue-Suissetd' Agriculture.* 25(5):271-275.

Rexen, R. 1976. Studies of protein of potatoes. *Potato Res.* 19:189.

Reynolds, T.M. 1965. Chemistry of non-enzymatic browning. *Adv. Fd. Res.* 14:167.

Roberts, E.A. and Proctor, B.E. 1955. The comparative effect of ionizing radiation and heat upon starch containing cells of potato tuber. *Fd. Res.* 20:254-263.

Rockland, B.L. and Hishi, K.S. 1980. Influence of water activity on food product quality and stability. *Fd. Technol.* 4:42.

Roe, M.A.; Faulk, R.M. and Belsten, J.L. 1990. Role of reducing sugars and amino acids in fry colour of chips from potatoes grown under different regimes. *J. Sci. Fd. Agric.* 52(2):207-214.

Roy Chaudhuri, R.N.; Joseph, A.A.; Ambrose, D.V.; Narayana, R.M.; Swaminathan, M.; Sreenivasan, A.; Subrahmanyan, V. 1963b. Effects of cooking, frying, baking and canning on the nutritive value of potato. *Fd. Sci.* 12:253-255.

Roy Chaudhuri, R.N.; Joseph, A.A.; Joseph, K.; Rao, M.; Swaminathan, M.; Sreenivasan, A.; Subrahmanyan, V. 1963a. Preparation and chemical composition of potato flour from some varieties of potato. *Fd. Sci.* 12:251-253.

Sagar, V.R. and Roy, S.K. 1997. Studies on packaging and storage of potato powder. *Indian Fd. Packer.* 51(6):67-71.

Salunkhe, D.K.; Jadhav, S.J. and Kadam, S.S. 1991. Potato : Production, processing and products, CRC Press. Boca Raton, F.L.

Sandhu, K.S.; Bawa, A.S.; Thind, S.S. and Sekhon, K.S. 1987. Evaluation of potato cultivars for processing. *Indian Fd. Packer.* 6:18-25.

Sangwan, S.S. 1991. Production and marketing of potato in India. Mittal Publications, New Delhi, 3-5, 44-45.

Sapers, G.M.; Panasiuk, O. and Tal, F.B. 1974. Flavour quality and stability of potato flakes : Effects of drying conditions, moisture content and packaging. *J. Fd. Sci.* 39:555-558.

Sapers, G.M.; Panasiuk, O.; Talley, F.B. and Shaw,R.L. 1973. Flavour quality and stability of potato flakes : Effects of raw material and processing. *J. Fd Sci.* 38:586.

Sapers, G.M.; Panasiuk, O.; Talley, F.B.; Osman, S.F. and Shaw, R.L. 1972. Flavours quality and stability of potato flakes : Volatile components associated with storage changes. *J. Fd. Sci.*, 37:579.

Schwimmer, S. and Burr, H.K. 1967. Structure and chemical composition of the potato tubers. In : Talburt, W.F. and Smith, O. 2nd ed. Potato processing. The AVI Publishing Company Inc., Westport, Connecticut,12.

Scrimshaw, N.S. and Young, V.R. 1976. The requirements of human nutrition. *Sci. Amer.* 235:64.

Shagina, L.A. and Lugovaya, N.P. 1993. Properties of stored fast-frozen potato puree. *Pischevaya – Promyshlennost,* Moscow, No. 8.15.

Sharma, K.P. 1987. Potato cultivation in India : Its past, present and future. *J. Indian Potato Assoc.* 14(3&4):79-87.

Sharon, L.D. 1985. Potato proteins. *In :* Paul, H.L. Potato physiology. London, 30.

Shaw, R.; Evans, C.D.; Munson, S.; List, G.R. and Warmer, K. 1973. Potato chips from unpeeled potatoes. *Amer. Potato J.* 50:424-430.

Shekhawat, G.S. 1999. 50 years of the Central Potato Research Institute. *In : Indian Farming.* 49(9):4-9.

Shekhawat, G.S. and Dahiya, P.S. 1997. Potato : Emerging paradigms. *In :* The Hindu Survey of Indian Agriculture. 67-71.

Shekhawat, G.S. and Ezekiel, R. 1999. Potato : Potential as a staple food. *In :* The Hindu Survey of Indian Agriculture. 73-74.

Shirsat, S.G. and Thomas, P. 1998. Effect of irradiation and cooking methods on ascorbic acid levels of four potato cultivars. *J. Fd. Sci. Technol.* 35(6):509-514.

Sikka, L.C. 1996. Potato research in India. *J. Indian Potato Assoc.* 23 (3&4):91-100.

Singh, M. 1993. Potato flour production and product formulation. Thesis, M.Sc., G.B. Pant University of Agriculture and Technology, Pantnagar, 35.

Singh, M. and Verma, S.C. 1979. Post harvest technology and utilization of potato. *In :* Kishore, H. Proceedings of the International Symposium on PHT and utilization of potato. International Potato Centre, New Delhi. 1-114.

Smith, A.K. and Circle, S.J. 1972. Soybean : Chemistry and technology. Westport. Connecticut. Vol. 1: 455-456.

Smith, O. and Laura, L.W. 1969. Nutritional value of the potato in relation to the food science industry. Proceedings of 19th National Potato Utilization Conference. Eastern Utilization Research and Development Division, Agriculture Research Service, U.S.D.A., Philadelphia, U.S.A. 59-72.

Smith, O. 1968. Potatoes-production, storing and processing. 1st ed. Westport. Connecticut, 542-642.

Snedecor, G.W. and Cochran, W.G. 1967. Statistical methods, 6th ed. Calcutta, Oxford and IBH Publishing Company.

Southgate, D.A.T. and White, M.A. 1981. Commentary on results obtained by the different laboratories using the Southgate method. *In* : James, W.P.T. and Theander, O. The analysis of dietary fiber in food. Vol. 3. New York and Basel Marcel Dekker Inc. 37-50.

Srivastava, S.N.S.; Singh, M. and Verma, S.C. 1973. Sun dry your surplus potatoes. *Indian Farming.* 17:16-17.

Staal, R.; Noz, H.; Loarhover, R.I. and Muan, G.J. 1990. Rehydration process in potato products methods for determination of water uptake by dried potato material. *Voeding Shniddlentechnologie.* 23(16/17):15-17.

Stahmann, M.A. and Woldegiorgis, G. 1975. Assay method – Biological, biochemical and chemical. *In:* Friedman, M. Protein nutritional quality of foods and feeds. Part I, volume I Marcel Dekker Inc. New York. 211-214

Steele, L.; Jadhav, S. and Hadziyev, D. 1976. The chemical assay of vitamin C in dehydrated mashed potatoes. *Lebensm Wiss Technol.* 9:239-245.

Stephenson, R.M.; Saho, T. and Harris, D.K. 1958. Storage characteristics of potato granules. *Fd. Technol.* 12:622-624.

Sterling, C. and Bettelheim, F.A. 1955. Factors associated with potato texture III. Physical attributes and genral conclusios. *Food Research.* 20:130-137

Stute, R. 1995. Use of potato granules in bread and fine bakery products. *Getreide, Meh and Brot.* 49(3):160-165.

Sukumaran, N.P. and Verma, S.C. 1993. Storage and processing. *In* : Chadha, K.L. and Grewal, J.S. Advances in horticulture. Vol. 7. Malhotra Publication House, New Delhi. 720-721.

Sun, H.H.; Chung, J.S.; Jung, I.K. 1995. Analysis of dietary fiber content of common Korean foods. *J. Korean Soc. Fd. Nutr.* 24(3):396-403.

Swaminathan, K. and B.M.L. Gangwar, 1961. Cooking losses of vitamin C in Indian potato varieties. *Indian Potato Journal.* 3:86-91.

Swaminathan, K. and Pushkarnath. 1962. Nutritive value of Indian potato varieties. *Indian Potato Journal.* 4(2):72-83.

Takahata, Y.; Noda, T. and Sato, T. 1995. Changes in carbohydrates and enzyme activities of sweetpotato lines during storage. *J. Agric. Fd. Chem.* 43(7):1923-1928.

Talburt, W.F. and Smith, O. 1975. Potato processing. 3rd ed, The AVI Publishing Company Inc. Westport, Connecticut.

Talburt, W.F. and Smith, O. 1987. Potato processing, 4th ed. AVI Publication Company. Westport, Connecticut.

Talley, E.A.; Toma, R.B. and Orr, P.H. 1984. Amino acid composition of freshly harvested and stored potatoes. *Amer. Potato J.* 61:267-274.

Temple, V.J.; Ojobe, T.O. and Onobun, C.E. 1991. Chemical composition of Living stone potato tubers. *J. Sci. Fd. Agric.* 56(2):215-217.

Theander, O. and Aman, P. 1981. Analysis of dietary fibers and their main constituents. *In :* James, W.P.T. and Theander, O. The analysis of dietary fiber in food. Vol. 3. New York and Basel Marcel Dekker Inc. 67.

Thorton, R.E. and Sieczka, J.B. 1980. Commercial potato production in North America. *Amer. Potato J.* 57.

Tomkins, R.G.; Mapson, L.W.; Allen, R.J.L.; Wager, H.G. and Barker, T. 1944. The drying of vegetables. The spoilage of dried vegetable. *J. Soc. Chem. Ind.* 63:225-231.

Treadway, R.H. 1949. Potato flour and its use in the baking industry. *Bakers Digest.* 23:82-84.

Treadway, R.H. 1987. Potato starch : *In :* Talburt,W.F. and Smith, O. ed. Potato processing. *Van Nostrand Reinhold Co.* New York, U.S.A., 659-663.

Treadway, R.H.; Willits, L.O.; Heisley, B.G.; Ross, L.R. and Osborne, M.F. 1950. Composition of flour from the 1948 potato crops. U.S. Dept. of Agriculture.

Trehan, S.P. and Sharma, R.C. 1996. Mineral nutrient composition in peels and flesh of tubers of potato genotypes. *J. Indian Potato Assoc.* 23(3&4):139-143.

Trowell, H; Southgate, D.A.T.; Wolever, T.M.S.; Leids, A.R; Gassull, M.A. and Jenkins, D.A. 1976. Dietary fiber redefined (letter) *Lancet.* 1: 967.

True, R.H.; Hogan, J.M.; Augustin, J.; Johnson, S.R.; Teitzel, C.; Toma, R.B. and Shaw, R.L. 1978. Mineral composition of freshly harvested potatoes. *Amer. Potato J.* 55:511.

True, R.H.; Hogan, J.M.; Augustin, J.; Johnson, S.R.; Teitzel, C.; Toma, R.B. and Orr, P. 1979. Changes in the nutrient composition of potatoes during home preparation. 3. Minerals. *Amer. Potato J.* 56:339.

Unrau, A.M. and Nylund, R.E. 1957. Physical and chemical aspects related to the mealiness in the potato. *Can.J. Pl. Sci.* 37:136-148.

USDA. 1963. Composition of foods – raw, procesed, prepared Agric. Handbook No. 8. U.S. Dept. of Agric. Washington, D.C. 50.

USDA. 1977. Agricultural Research Service. The commercial storage of fruits, vegetables, flourist and nursery stocks. Agriculture Handbook No. 66. United State Dept. of Agriculture.

Vaidehi, M.P. 1987. Potato recipes for you and me. I. Boiling and frying methods. *J. Indian Potato Assoc.* 15(1&2):94-108.

Vaidehi, M.P. 1988. Potato recipes for you and me. II. *J. Indian Potato Assoc.* 15 (3&4):171-185.

Vaidehi, M.P. and Sananda, P.K. 1982. Dehydrated products of potatoes. *J. Indian Potato Assoc.* 9(1):21-27.

Van Arsdel, W.B. and Coopley, M.J. 1964. Food dehydration. Vol. II. Westport, Connecticut. 303-317.

Vencken, C.M.J. and Ebbenhorst, G. 1990. Effects of processing and storage on the vitamin content of potato flakes. *Voedingsmiddelentechnologie.* 23(24):9-12.

Verma, S.C. 1977. Food value of potato. *In :* Nagaich, B.B. Recent technology in potato improvement and production. CPRI, 299-303.

Verma, S.C.; Joshi, K.C.; Sharma, T.R. and Malhotra, V.P. 1975. Dry matter content of potato varieties grown at different locations. *J. Indian Potato Assoc.* 2:15-17.

Wager, H.G. 1963. The role of phytin in texture of cooked potatoes. *Journal of Sci. Food Agric.* 14:583-586.

Waghmare, N.V.; Kotecha, P.M. and Kadam, S.S. 1999. Effects of pre-treatments, storage of potato and antioxidants on qulaity of potato chips prepared from cultivars grown in western Maharashtra. *J. Fd. Sci. Technol.* 36(1):49-51.

Wang, X.Y.; Kozempel, M.G.; Hicks, K.B. and Seib, P.A. 1992. Vitamin C stability during preparation and storage of potato flakes and reconstituted mashed potatoes. *J. Fd. Sci.* 57(5):1136-1139.

Warren, D.S.; Gray, D. and Woolan, J.S. 1975. Relationship between chemical composition and breakdown in cooked potato tissue. *J. Sci. Fd. Agric.* 25(1):124-138.

Watt, B.K. and Merill, A.L. 1963. Composition of foods. Agriculture handbook No. 8, USDA, Washington, D.C.

Weaver, M.L.; Timm, H.; Nag, H. 1983. Changes in nutrition composition of "Russet Burbank" potatoes by different processing methods. *Amer. Potato J.* 60:735-744.

Whistler, R.D.; Spencer, W.W.; Goatley, J.L. and Nikune, Z. 1958. Effect of drying on the presence of cavities in corn starch granules. *Cereal Chemistry.* 35:331-336.

Whitley, P.R. 1970. Biscuit Manufacture Applied Science Publishers Ltd., London, U.K.

Willard, M. 1967. Potato flour. *In :* Talburt, W.F. and Smith, O. Potato procesing 2nd ed. The AVI Publishing Company, Westport, Connecticut. 582.

Willard, M.J. and Englar, W.J. 1959. Factor influencing the water absorption of potato flour. Presented at the Institute of Food Technology, Philadelphia, Pennsylvania.

Willard, M.J. and Hix, V.M. 1987. Potato flour. In : Talburt, W.F. and Smith, O. Potato processing. Van Nostrand Reinhold Co., New York, U.S.A., 675.

Wills, R.B.H. and Silalahi, J. 1990. Effects of storage temperature on loss of vitamin C in potato crisps. *J. Sci. Fd. Agric.* 53(2):275-278.

Wilska, J.S. and Boruch, M. 1979. *ZeszNauk,* Polit Lodz. 33(295): 103-110.

Wood, R.K.S.; Gold, A.H. and Rawlin, T.E. 1952. Electron microscopy of primary call walls treated with pectin enzymes. *American Journal of Botany.* 39:132-133.

Woodward, C.F. and Talley, E.A. 1953. Review of the nitrogenous constituents of the potato. Nutritive value of the essential amino acids. *Amer. Potato J.* 30:205.

Yanez, E.; Ballester, D.; Wuth, H.; Orrego, W.; Galtas, V. and Estay, S. 1981. Potato flour as partial replacement of wheat flour in bread : baking studies and nutritional value of bread containing graded levels of potato flour. *J. Fd. Technol.* 16:291-298.

APPENDIX- I

Range and mean of maximum and minimum temperature recorded during 3 and 6 months storage of potato flour at room and refrigerated temperature

3 months storage - from 1st May, 1999 to 1st August, 1999

6 months storage - from 1st May, 1999 to 1st November, 1999

Duration of storage	**Range of max. temp. (^0C)**	**Average (^0C)**	**Range of min.temp. (^0C)**	**Average (^0C)**
May 1-31	31.70-42.50	37.10	16.90-26.80	21.85
June 1-30	29.90-40.50	35.20	18.90-28.30	23.60
July 1-31	29.90-35.60	32.75	23.20-28.30	25.75
August 1-31	27.00-33.80	30.40	23.20-26.50	24.85
Sept. 1-30	25.70-32.50	29.10	22.40-25.70	24.05
Oct. 1-31	26.90-31.60	29.25	13.90-23.50	18.70
Nov. 1-30	24.20-31.50	27.85	7.90-16.60	12.25

APPENDIX-II

Score card for sensory evaluation of food products

Name : **Date :**
Product :

Kindly evaluate the given samples for different characters as follows:

Quality factors	Max. Score	801	923	112	453	784	537	293
Appearance	10							
Colour	10							
Flavour	10							
Texture	10							
Taste	10							
Overall acceptability	10							

Scoring scale:	1-2	3-4	5-6	7-8	9-10
	very poor	poor	fair	good	very good

Comments

Signature

APPENDIX- III

Equilibrium relative humidity of potato flour (OP-1)

ERH* (%)	EMC** (%)					Remark
	Fresh flour	3 months (Room temp.	3 months (Refrigerated)	6 months (Room temp.)	6 months (Refrigerated)	
0	3.05	3.77	3.45	4.19	3.49	Free flowing, colour not affected
11.2	4.76	6.07	5.52	6.23	5.57	-do-
22.0	7.21	7.96	7.46	8.33	7.51	-do-
32.4	9.05	10.68	9.74	11.29	9.82	-do-
43.5	10.76	12.86	11.08	13.19	11.19	-do-
51.4	12.61	14.80	12.91	15.35	12.98	Slight moist
63.3	15.74	18.79	16.12	19.09	16.19	Moist, cake formation
71.4	20.29	23.88	21.95	24.25	22.21	Caky and moist, mould appeared after 11 days
79.6	25.80	29.93	27.50	30.22	27.59	Caky and moist, mould appeared after 9 days
86.3	30.02	34.68	31.97	35.12	32.08	Caky, mould appeared after 8 days
92.0	34.11	37.24	35.15	37.55	35.21	Caky, mould appeared after 6 days

* **Equilibrium Relative Humidity**

** **Equilibrium Moisture Content**

APPENDIX- IV

Equilibrium relative humidity of potato flour (K.Sutlej)

ERH* (%)	EMC** (%)					Remark
	Fresh flour	3 months (Room temp.	3 months (Refrigerated)	6 months (Room temp.)	6 months (Refrigerated)	
0	3.11	3.81	3.52	4.17	3.69	Free flowing, colour not affected
11.2	4.78	6.15	5.63	6.21	6.01	-do-
22.0	7.25	8.02	7.54	8.37	7.92	-do-
32.4	9.12	10.73	9.86	11.33	10.64	-do-
43.5	10.79	12.95	11.21	13.14	12.79	-do-
51.4	12.64	14.89	12.95	15.38	14.74	Slight moist
63.3	15.76	18.74	16.19	19.12	18.71	Moist, cake formation
71.4	20.31	23.85	22.25	24.31	23.76	Caky and moist, mould appeared after 11 days
79.6	25.84	29.97	27.54	30.35	29.87	Caky and moist, mould appeared after 9 days
86.3	30.05	34.76	32.13	35.16	34.63	Caky, mould appeared after 8 days
92.0	34.14	37.28	35.18	37.59	37.19	Caky, mould appeared after 6 days

***** **Equilibrium Relative Humidity**
****** **Equilibrium Moisture Content**

APPENDIX- V

Equilibrium relative humidity of potato flour (K.Ashoka)

ERH* (%)	EMC** (%)					Remark
	Fresh flour	3 months (Room temp.	3 months (Refrigerated)	6 months (Room temp.)	6 months (Refrigerated)	
0	3.41	3.84	3.69	4.19	3.76	Free flowing, colour not affected
11.2	5.48	6.21	6.01	6.25	6.08	-do-
22.0	7.41	8.11	7.91	8.39	7.97	-do-
32.4	9.66	10.79	10.62	11.37	10.64	-do-
43.5	11.01	13.01	12.79	13.15	12.84	-do-
51.4	12.87	14.95	14.74	15.41	14.80	Slight moist
63.3	16.04	18.83	18.71	19.17	18.79	Moist, cake formation
71.4	21.89	23.91	23.76	24.35	23.85	Caky and moist, mould appeared after 11 days
79.6	27.41	30.02	29.89	30.38	29.91	Caky and moist, mould appeared after 9 days
86.3	31.87	34.83	34.63	35.19	34.66	Caky, mould appeared after 8 days
92.0	35.09	37.31	37.19	37.63	37.24	Caky, mould appeared after 6 days

*** Equilibrium Relative Humidity**
**** Equilibrium Moisture Content**

VITA

1971	Born on July 27 at Kanpur
1987	Passed X standard (CBSE Board) with first division from Campus School, Pantnagar
1989	Passed XII standard (CBSE Board) with first division from Campus School, Pantnagar
1992	Passed B.Sc. (Home Science) Honours with an OGPA of 4.941/5.000 from the college of Home Science, GBPUA&T, Pantnagar. Recipient of University Merit Scholarship and honoured with Vice-Chancellor's Gold Medal for being the best graduating student.
1993	Joined one and a half years Honours Diploma in Systems Management at NIIT, Kanpur.
1996	Passed M.Sc. (Food & Nutrition) with an OGPA of 8.24/10.00 from CSAUA&T, Kanpur. Awarded University Silver Medal for securing second position.
1997	Joined Ph.D. (Human Nutrition) at GBPUA&T, Pantnagar and was recipient of University Fellowship.

ABSTRACT

Name of student: Anupama Misra Id.No. 18048
Semester & Year of admission: II Sem.,1996-97 Department: Foods & Nutrition
Advisor: Dr.(Mrs.) Kalpana Kulshrestha

Thesis Title: "QUALITY CHARACTERISTICS AND UTILIZATION OF POTATO FLOUR"

Three different potato varieties viz. 'OP-1', 'Kufri Sutlej' (K.Sutlej) and 'Kufri Ashoka' (K.Ashoka) were processed into flour using simple technology. The flours prepared were studied for their physico-chemicl characteristics, nutritional value and microbial load. The effect of storage on these characteristics of potato flour was also studied after 3 and 6 months storage, both at room and refrigerated temperatures. Different food products i.e. biscuit, sev and idli were prepared using different proportions of potato flour and sensory quality attributes were evaluated by score card method. The product with the highest accepted level in each of the three varieties was studied for nutritional value. Among the physico-chemical characteristics, the colour of potato of all three varieties was rated as pale yellow, the water absorption capacity and particle size index differed significantly in the varieties, and the moisture sorption isotherm showed that all the potato flours can be stored safely upto 50 per cent relative humidity, without affecting its quality. Storage had no effect on colour, particle size index and moisture sorption isotherm of potato flour, but showed a decreasing trend in water absorption capacity. Regarding the nutritional value of potato flour, three varieties showed similar moisture content ('OP-1' – 8.08%, 'K.Sutlej' – 8.10% and 'K.Ashoka'- 8.48%). The protein content of varieties 'OP-1' (10.48%) and 'K.Sutlej' (10.33%) differed significantly from variety 'K.Ashoka' (9.24%). The total ash content of variety 'OP-1' (3.09%) differed significantly with that of 'K.Ashoka' (2.56%) 'OP-1' showed highest starch content (78.04/100g) and highest calcium content (21.76 mg/100g). Phosphorus content of varieties 'OP-1' (188.57 mg/100g) and 'K.Sutlej' (177.73 mg/100g) were similar and iron content of varieties 'OP-1' (3.93 mg/100g) and 'K.Ashoka' (3.89 mg/100g) were similar. Also the ascorbic acid content of variety 'OP-1' (8.70 mg/100g) and 'K.Ashoka' (7.12 mg/100g) were similar. *In vitro* protein digestibility of variety 'K.Sutlej' (75.89%) and variety 'OP-1' (77.00%) differed significantly from 'K.Ashoka' (72.85%). Total dietary fiber content of varieties 'OP-1' and 'K.Ashoka' were similar. Storage of potato flour upto six months had no effect on protein, ash, total starch, calcium, phosphorus, iron, *in vitro* protein digestibility and dietary fiber content. The moisture content increased whereas, ascorbic acid content decreased during 6 months storage of potato flour. Sensory evaluation of the food products showed that biscuits and idli prepared from 20% potato flour incorporation and sev prepared from 40% potato flour incorporation were similar to the control and these were the highest level accepted. The nutritional value of potato flour incorporated food products viz. biscuit, sev and idli was statistically similar to the control samples. Microbial load of potato flour showed that lowest bacterial count was recorded in variety 'OP-1' ($1.65x10^3$). The bacterial count increased during 6 months storage for all the flour but was within the limits prescribed by ISI specification.

(Kalpana Kulshrestha)
Advisor

(Anupama Misra)
Authoress