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A MANUAL ON POTATO PROCESSING IN INDIA

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FOREWORD

Agri-processing sector experiences very fast growth rate when an economy transforms from developing to developed one. The rise of Indian economy from present $ 1.57 to between 13 and 34 trillion by 2050 (under varied scenarios; NCAP estimates) is not possible without corresponding rise in agri-processing industry. Further, potato is always the front-runner when we take processing of agri-commodities into consideration. At present 1210 million people of India consume potato mainly as vegetable. However a population of much richer 1619 million people (NCAP estimates) during 2050, out of which more than 840 million being urban (against the current 375 million) and much higher proportion of working women and nuclear families, will totally transform the demographic structure of India. Incidentally this change will be conducive for higher demand for potato (as vegetables and fast food ingredients) and processed potato products in the future. Fast increment in per capita as well as total household consumption of potato in India during recent past is expected to sustain in the foreseeable future hence; there is great potential of enhancing potato processing in the country.

Analysis of past experience and pattern of Indian processing industry suggests that demand for processing quality potatoes over next 40 years will rise at the fastest pace for French fries (11.6% ACGR) followed by potato flakes/ powder (7.6%) and potato chips (4.5%). The actual demand for processing potatoes will rise from 2.8 million t in 2010 to 25 million t during the year 2050 at an ACGR of 5.61% (CPRI Vision 2050). The total demand of processed potato products is estimated to rise from 0.7 million t in 2010 to 7.3 million t in 2050 leading to increase in corresponding per capita demand for processed potato products from 0.6 to 4.5 kg (6.03% ACGR) over the period of 40 years.

To sustain this incremental growth in potato processing sector, the industry has to be supported by the required technologies including the need for improved processing varieties. The compilation of this manual on potato processing is an attempt in this direction for providing the technical knowhow to the unorganised and organised processing industries in the country. The information is expected to strengthen the industry in making decisions on procurement of desired raw material, quality testing and final processing into desired products.

2016
Shimla

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PREFACE

The processing of potatoes in India was not in vogue till 90's and with the openings of organized processing by multinationals and indigenous players, potato processing industry has grown manifolds. Presently about 7.5% of potato production is being used for processing and the major part of potato harvest (approximately 68.5%) goes to domestic table consumption. Whereas, in the developed countries, table potato utilization is merely 31%, rest being frozen French fries (30%), chips and shoestrings (12%) and dehydrated products (12%). The pattern of Indian potato industry suggests that the demand for potatoes for processing purpose is expected to rise rapidly over next 40 years for French fries (11.6% ACGR) followed by potato flakes/ powder (7.6%) and potato chips (4.5%). At this pace, the demand for processing quality potatoes is expected to rise to 25 million t during the year 2050.

Potatoes can be processed into various forms such as chips, fries, dehydrated products (dehydrated chips, dice or cubes, *waris,* papads, flakes, granules and flour) potato starch, etc. Potato processing is carried out both by organized and unorganized sectors. Organized sector mainly involves large manufactures with brand names. Whereas, small manufactures that are preparing processed potato products for local market without any brand name come under unorganized sector. Along with potato chips, dehydrated potato products such as potato shreds and potato chips are also made by unorganized sector.

To achieve the Vision 2050 targets, it is the need of the hour that proper technical support is provided to the processing sector. The present bulletin is an attempt to compile all the technical knowhow for the sector starting from the quality requirements to suitable varieties, their availability, suitable areas for production of processing varieties and technologies for processing potatoes into several products. We hope that the manual will be very handy for all the potato processing stakeholders of the country, particularly for the unorganized and small processing units. Simultaneously, it may

also help the organized sector to get the information on quality aspects.

We thank Dr. NK Pandey, Head and Dr. Dhiraj K. Singh, Scientist, Division of Social Science for making available the latest data on area, production and productivity.

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Introduction

Potato is one of the world's major agricultural crops and is the most important and versatile food. Potato production in Asia today accounts for a great share of global output mainly as a consequence of introduction of new technologies, improvement in production and post-harvest infra structures and government policies as well (Scott and Suarez, 2012). It contributes in two different ways to the lively-hoods of the poor i.e., it contributes directly to hunger reduction (as a staple food) and principally to poverty reduction by increased income or by creating employment. Potato consumption is greatest in Western world and is slowly obtaining the status of staple food in developing countries resulting in an increase in per capita consumption of fresh potatoes at an ACGR of 2.34% during 1991 to 2010 (Vision 2050).

In India, potatoes have been utilized largely for consumption as fresh potatoes and the major part of potato harvest (approx. 68.5%) goes to domestic table consumption. Figure 1 shows the major potato growing states in India. Whereas, in the developed countries, table potato utilization is merely 31%, rest being frozen French fries (30%), chips and shoestrings (12%) and dehydrated products (12%). The processing of potatoes in the country was not in vogue till 90's and with the openings of organized processing by multinationals and indigenous players, potato processing industry has grown manifolds. In India, potato processing industry has shown tremendous growth during the past decade. Demand of fresh potatoes in the year 2010 was 19.78 kg per capita and 23.94 million tonnes was the national demand which is expected to increase to 48.47 kg and 78.47 million tonnes, respectively by the year 2050. During 2007-2008 about 7.5 % of potato production was used by processing industry and the sector is still increasing at a rapid rate. The pattern of Indian potato industry suggests that the demand for potatoes for processing purpose is expected to rise rapidly over next 40 years for French fries (11.6% ACGR) followed by potato flakes/ powder (7.6%) and potato chips (4.5%). The demand for processing quality potato is expected to rise to 25 million tonnes by the year 2050. Demand for raw material for potato processing was 2.45 million tonnes for chips, 0.29 million tonnes for potato flakes/

powder and 0.06 million tonnes for frozen potato products in the year 2010, which is expected to increase to 14.22, 5.44 and 5.40 million tonnes respectively, in the year 2050 (Vision 2050).

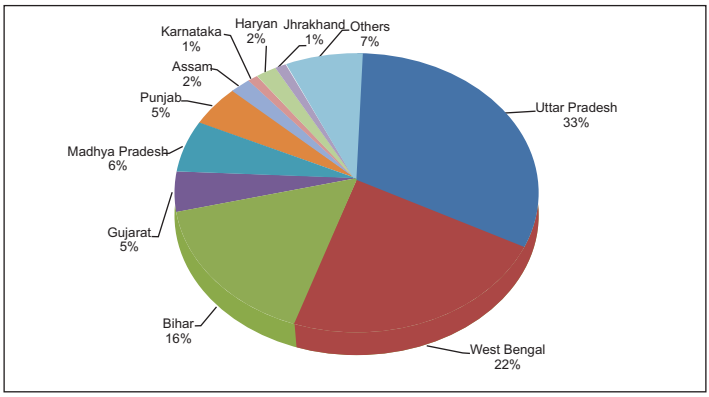


Figure 1: Leading potato producing states in India (2013-14)
(Source: Indian Horticulture Database-2014, National Horticulture Board)

1.1 Need for potato processing in India

Potato production in India has shown a steady increase in the last 50 years (Figure 2). Increase in production, often resulting in gluts at harvest, has led to several post-harvest issues like storage and proper utilization of the produce. About 90 per cent of the potato crop in the country is harvested during January-February from the Indo-Gangetic plains comprising the states of Punjab, Haryana, Uttar Pradesh (U.P.), Bihar, West Bengal, Madhya Pradesh (M.P.) and Gujarat (Figure 1) where the harvest is followed by rising temperatures of hot and dry summer and further by warm and humid

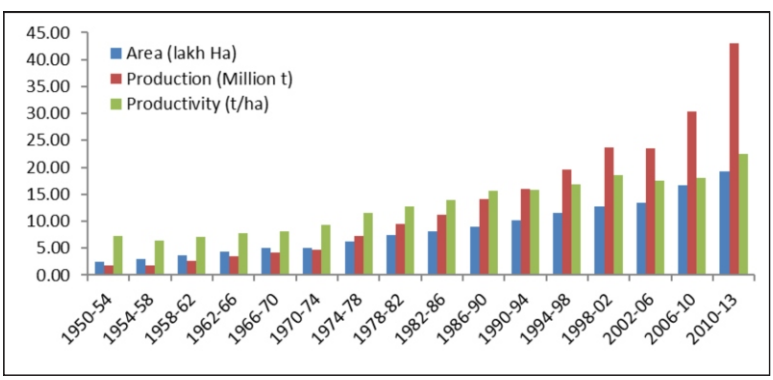


Figure 2: Increase in Area, Production and Productivity in India

rainy season. Since potato tubers contain about 80% water, under such circumstances, a semi-perishable commodity like potato, cannot be stored for more than 3-4 months without refrigeration because of very high losses to the produce due to shrinkage, sprouting and attack by microorganisms. Therefore, these potatoes either need to be stored at low temperatures or processed into some products.

Along with increase in potato production there is an urgent need to increase the rate of potato consumption also, to avoid the wastage. The demand for processing potatoes and processed potato products like chips, French fries, *lachcha,* flakes etc. is increasing continuously in the present liberalized economy mainly due to improved living standard, increased urbanization, preference for fast foods, rise in per capita income, increase in the number of working women preferring ready-cooked food and an expanding tourist trade (Figure 3-4). In case of potato farmers, there is ample entrepreneurial opportunity to prepare processed potato products to fetch good prices. Potato processing can save their produce from market gluts, high rates of cold storage facilities and also will generate income source for them, especially for unemployed youth.

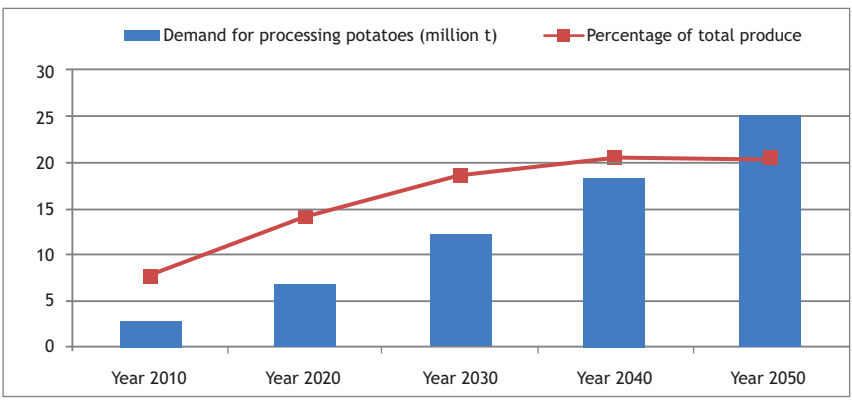


Figure 3: Demand for processing potatoes in future (million tonnes)

(Source: Vision 2050, CPRI, Shimla)

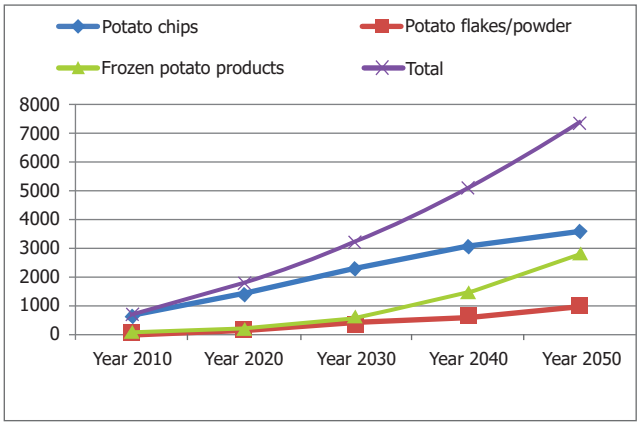


Figure 4: Demand for potato products in future (thousand tonnes)

(Source: Vision 2050, CPRI, Shimla)

1.2 Present potato processing scenario

Potatoes can be processed into various forms such as chips, fries, dehydrated products (dehydrated chips, dice or cubes, *waris,* papads, flakes, granules and flour) and potato starch etc. Potato processing is carried out by both organized and unorganized sectors. Organized sector mainly involves large manufactures with brand names. Whereas, small manufactures that are preparing processed potato products for local market without any brand name come under unorganized sector. Organized sector mainly prepares French fries, *Aloo Bhujia,* potato flakes and flour. Potato chips are prepared by both organized and unorganized sectors. Along with potato chips, dehydrated potato products such as potato shreds and potato chips are also made by unorganized sector.

Organized sector: Potato chips production by the organized sector increased rapidly after the introduction of the liberalization policy of the government of India. The organized sector in the country produces about 30,000 tonnes of potato chips per year. Popularization of potato chips by companies such as Frito Lays India has led to fast incremental growth in potato chip manufacturing capacities. Frito Lays India and ITC retained approximately 31.55% share of potato chips market during 2010-2011. Besides these, some other organized players as of date at

national and regional levels include Haldiram, Kishlay, Balaji, Uncle chips etc. The demand for potato chips is likely to increase further, because of its increasing popularity as a convenient fast food especially in urban areas. The second popular product is potato *lachcha* and *lachcha* market is also dominated by branded manufacturers. *Aloo bhujia*, which contains potato only as one of the ingredients, is also quite popular and the *Aloo bhujia* market is dominated by Lehar and Haldiram. There is a series of frozen products being marketed by firms like McCains and Merino Industries, which are gaining fast popularity in the Indian market (Figure 5).

Figure 5: Potato products from organised sector

Unorganized sector: Potatoes are also being processed at small scale in rural India (Figure 6). Potato processing in the unorganized sector is of considerable importance in a country like ours where majority of the population cannot afford to purchase potato chips produced by the organized sector which costs Rs. 300 per kg. Potato chips produced by the unorganized sector costs Rs. 150 to Rs. 200 per kg. In India, approximately 377 thousand tonnes of potato chips are prepared by unorganized sector. In Kolkata alone, there are about 200 small units producing processed products from potatoes. Small scale potato processors are found in almost all cities and towns in the country and they produce a variety of products like potato chips, potato *lachcha*, potato *bhujia*, potato pops, potato *papads*, dehydrated potato chips etc. Dehydrated potato chips and potato flour are being produced by several small scale potato processors in the country.

Figure 6: Potato chips processing at an unorganized sector

Although the price of the potato chips produced by the unorganized sector is low, the quality of the chips is poor compared to that produced by the organized sector. The chips produced by the unorganized sector can have up to 80% browning, up to 50% broken pieces and 10% green chips.

Tuber Quality Considerations for Processing

Potatoes are being processed into different products such as chips, French fries, flakes, granules and canned potatoes etc. Different processing techniques are involved in preparation of these products. Therefore, there is a variation in the raw material requirement for such a range of products. Quality of processed potato product depends on the quality of the raw material. The quality of raw material is judged by two factors viz. morphological characters as well as biochemical composition of the variety.

2.1 Morphological characters

Among the morphological characters, shape and size of the potatoes are of utmost importance. For preparation of chips round to round-oval potatoes are preferred whereas, for preparation of French fries, long oval potatoes are preferred (Figure 7). Large sized potatoes are preferred for processing to avoid peeling losses as small tubers have large surface area in relation to their weight. There is 16% difference in peel losses in tubers with diameter of 25 mm and 50 mm. Potatoes should meet some basic requirements for preparing chips and French fries since the quality of product is determined by its appearance (i.e. colour), crispiness and taste. Light or light golden yellow colour is desirable, whereas brown or black colour is undesirable in chips and French fries. Potatoes of 40-60 mm diameter and above are suitable for preparation of chips and French fries. Small sized potatoes are used for canning. Moreover to avoid losses during peeling and to maintain the shape of the slices, potatoes with shallow eyes are preferred for processing into chips and French fries.

Figure 7: Tubers of Kufri Chipsona 1 and Kufri Frysona

2.2 Chemical composition of potato

Potatoes contain about 80% water and 20% dry matter. On fresh weight basis, almost 14-16% of potato dry matter is starch. Indian potatoes contain around 2% protein, 0.6% fibre and 1% minerals. Fat content in raw potatoes is only 0.1%. Potato is a substantial source of ascorbic acid, thiamine, niacin, pantothenic acid and riboflavin. Potatoes also contain a variety of health-promoting compounds, such as, phytonutrients. Among these, important health-promoting compounds are carotenoids, flavonoids, and caffeic acid, as well as unique tuber storage proteins, such as patatin. Among the antinutrients, potatoes accumulate some alkaloids called glycoalkaloids when exposed to sunlight and their main constituents are α-chaconine and α-solanine. Normally, they contain less than 5 mg α-solanine per 100 g fresh weight which is far lesser than the safety limit of 20 mg/100 g. Glycoalkaloid content of potato is so low that it is not even perceptible by taste (Singh et al 2015).

2.3 Dry matter content

Among the biochemical attributes, dry matter and reducing sugars are considered as of utmost importance. Potatoes with high dry matter are preferred for fried and dehydrated products and with low dry matter are used for canning. The dry matter content of potato determines the yield of the products and the quantity of oil absorbed during frying. High dry matter leads to higher yield of products with lower oil content. A dry matter content of 18-20% is considered acceptable for canning and for chips, French fries and dehydrated products the desired dry matter content is 20% or more.

Major advantages of using high dry matter potatoes for dehydrated and fried products are:

a) Lower energy requirement for removing water either during frying or dehydration

b) Lower uptake of cooking medium during frying as compared to potatoes containing low dry matter

c) Higher yield of the product.

Potato varieties differ in their dry matter content. Generally, late maturing varieties contain high dry matter, as compared to early maturing varieties. Level and type of fertilizers also have an effect on the dry matter content of potatoes. Application of higher doses of nitrogenous fertilizers to crop results in lower dry matter containing potatoes. Application of muriate of potash for the supply of potassium to the crop results in potatoes with lower dry matter content, as compared to those which are supplied with sulphate of potash.

2.4 Relationship between dry matter content and specific gravity of potatoes

Dry matter content of potatoes in processing plants is generally determined by an indirect method involving estimation of specific gravity of the tubers. The specific gravity is generally determined by using either salt solution of known specific gravity or through the use of a potato hydrometer or by applying the Archimedes's principle as under:

$$\frac{\text{weight in air}}{\text{weight in air - weight in water}}$$

It has been established that the specific gravity of potatoes is directly proportional to their dry matter content i.e the dry matter content of potatoes increases with an increase in their specific gravity. However, the regression values for conversion of specific gravity to dry matter content need to be worked out for different locations and varieties.

2.5 Reducing sugars content

The acceptability of fried potato products depends on the level of the reducing sugars (glucose and fructose) present in the raw material. This is due to their function in the development of undesirable colour during frying. Chips and French fries prepared from potatoes containing high sugars turn brown and black and become unacceptable to the consumers. Potatoes contain appreciable

amount of sucrose, glucose and fructose as well as many other sugars in small quantities. At the time of harvest of mature potatoes, the sugar content is generally low, about 0.5 to 1% by weight. One half of this quantity is accounted for by sucrose, and the other half by glucose and fructose taken together. Glucose and fructose are known as reducing sugars and are the ones generally involved in the development of undesirable colour along with bitter taste. For preparing good quality potato chips, the reducing sugars content should be less than 150 mg/100g tuber fresh weight. If the level of reducing sugars is more than this, the fried product becomes dark in colour and unacceptable. The dark colour is formed due to a reaction called 'Maillard reaction' between reducing sugars and free amino acids (Figure 8). Maillard reaction takes place during the high temperatures of frying.

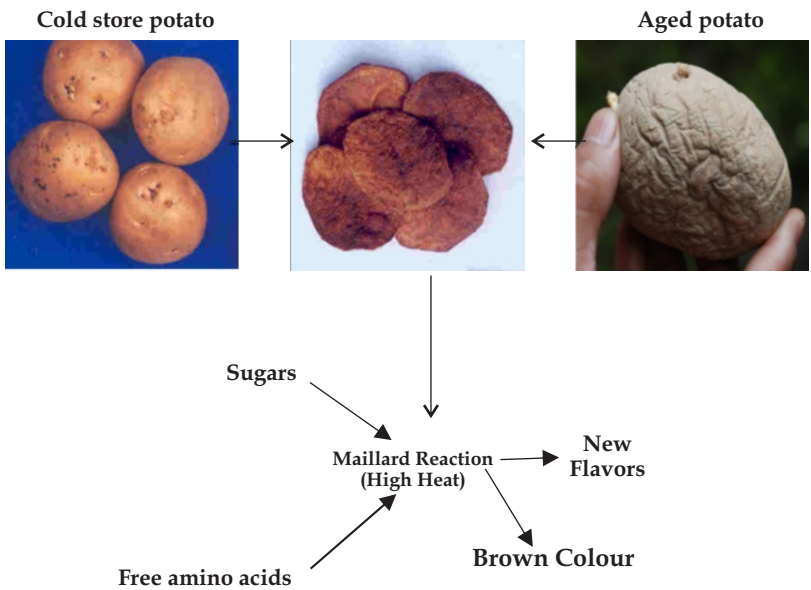


Figure 8: Maillard reaction and dark coloured chips

For uniform ranking of colour in potato chips, colour cards have been developed by ICAR-Central Potato Research Institute (Figure 9). These colour cards have scores of 1-10, higher the colour score more is the browning. A colour score up to 3-4 is acceptable while 5 and above is considered unacceptable in the industry.

Figure 9: Colour cards for potato chips

The Maillard reaction which produces dark colouration in potato products is also responsible for production of another unwanted compound 'acrylamide' as a by-product of the reaction between amino acid 'asparagine' and reducing sugars. Since acrylamide has been categorized as a carcinogen, there is high concern for its concentration in the processed potato products. All the Indian varieties have been profiled for the formation of acrylamide in the chips and French fries and the results have clearly shown that the varieties known for good processing quality having low reducing sugars also produce less acrylamide in the products and hence, it is recommended that for processing of potatoes, only processing varieties may be utilized.

2.6 Sucrose content

Sucrose is the major form of free sugar found in immature potatoes. Although sucrose does not participate directly in the unfavourable Maillard reaction during potato processing, it serves as a substrate for reducing sugar production via the activation of invertase enzyme during storage. Therefore, the concentration of sucrose at harvest is a critical factor determining the initial rate of reducing

sugar formation in a variety and thus affecting its processing quality.

2.7 Discolouration

Discolouration in fried potato products occurs due to Maillard reaction as mentioned above. Except that, two other types of discoloration occur in potato. One is enzymatic discolouration which is also known as enzymatic browning. This type of discolouration occurs due to the presence of polyphenol oxidase enzyme in potato and that can be seen in peeled, cut and injured potatoes. Enzymatic discolouration can be prevented by reducing the exposure of peeled and cut potatoes to air by keeping them immersed in water and also by blanching treatments to some extent. Second type of discolouration is after cooking discolouration, which develops in potatoes after cooking and on exposure to air. This type of discolouration is a concern for canners, however, in India it is not a major concern as Indian varieties are free from this defect.

2.8 Quality requirement for different products

Selection of raw material is based on the requirement for end product. Size, shape and biochemical constitution of raw material vary from product to product (Table 1).

Table 1: Quality requirement

Product	Shape	Size (Diameter)	Dry matter (%)	Reducing sugars (mg/ 100g FW)
Chips	Round	45 -80 mm	> 20	<150
French Fries	Oblong	>76 mm	> 20	<150
Potato flakes	Any shape	Not specific	> 20	<100
Canning	Any shape	20 -40 mm	<18	Not specific
Starch	Any shape	Not specific	22 -24	Not specific
Dehydrated products	Any shape	30 mm	22 -25	<150

Suitability of Indian Potato Varieties for Processing

Indian potato varieties were mainly developed for consumption as fresh potatoes until late 90's. Among these, only few varieties have desirable morphological characters, high dry matter and acceptable reducing sugar level for processing purposes, which include Kufri Jyoti, Kufri Chandramukhi and Kufri Lauvkar. With the emphasis on developing processing varieties, the varieties viz. Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chipsona-3, Kufri Chipsona-4, Kufri Frysona and Kufri Himsona have been developed and few more are in pipeline. All these processing varieties released by ICAR-CPRI meet the morphological and biochemical requirement for processing (Figure 10). Kufri Chipsona-1 and Kufri Chipsona-2, besides providing yield equal to Kufri Jyoti in the Indo-Gangetic plains, possess good resistance to late blight. Due to the cultivation of processing potato varieties on large areas in India, the availability of raw material for processing is no longer a constraint. Tuber characters and processing quality of these varieties are shown in Table 2.

Table 2: Tuber characters and processing quality of some Indian potato varieties

Variety	Crop Duration	Shape/Size	Eyes	Dry matter (%)	Reducing sugars (mg/100g FW)	Acrylamide (µg/Kg FW)
Kufri Chipsona -1	100 -110 days	Oval/Large	Fleet	21 -24	45 -100	< 100
Kufri Chipsona -2	100 -110 days	Round/Large	Fleet	21 -25	44 -93	<100
Kufri Chipsona -3	90 -110 days	Round -Oval Medium	Fleet	22 -24	30 -50	< 1 00
Kufri Chipsona -4	90 -110 days	Round	Fleet	21 -23	60 -140	< 1 0 0
Kufri Frysona	90 -110 days	Oblong/ Large	Fleet	22 -23	<100	< 100
Kufri Himsona	110 -120 days	Oval/ Medium	Fleet	20 -25	<50	< 1 00
Kufri Jyoti	90 -100 days	Oval/Large	Fleet	18 -21	106 -275	< 800
Kufri Lauvkar	80 -85 days	Round/Large	Fleet	18 -20	200 -250	< 300
Kufri Chandramukhi	80 -85 days	Oval/large	Fleet	18 -20	250 -324	< 500

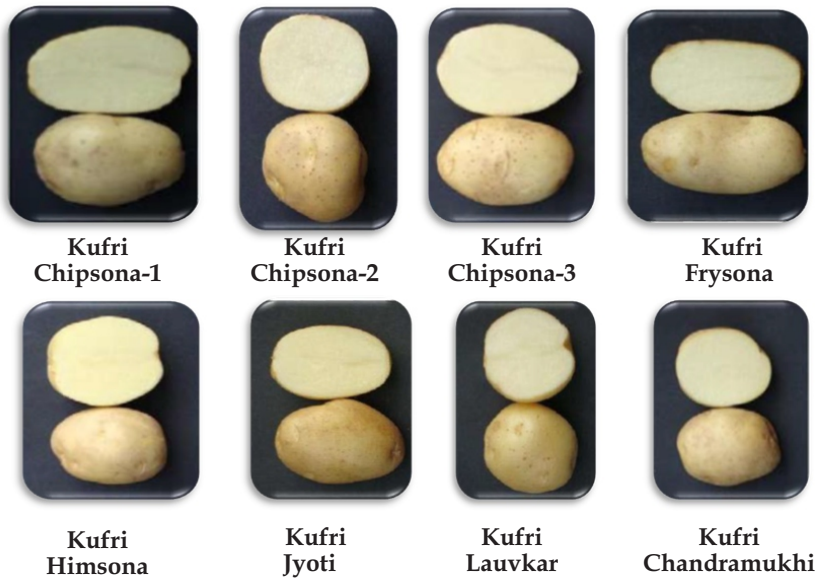


Figure 10: Shape of processing varieties developed by CPRI

Potato Processing in Temperate vs Subtropical Countries

Potato processing started more than a hundred years ago in temperate countries and expanded greatly after the Second World War. In the temperate countries, potato is grown for a longer duration of 5-6 months. The crop is grown under long day conditions and warmer temperatures. The day length varies from 15 to 16 hour and the temperature varies from 15 to 25°C. The potato crop receives about 2,600 hours of solar radiation and the productivity is 16.9 kg/ha/h. Depending upon the variety and agro-climatic conditions, the dry matter content varies from 18% to 25%. The varieties used for processing have a dry matter content of 20% or more.

During the nineties, the Indian potato processing industry showed 15-20% growth. The quantity of potatoes being processed at present is approximately 7.6% of the total production. The potato varieties in India were developed primarily for table purposes. However, two of these varieties viz. Kufri Jyoti and Kufri Lauvkar were found suitable for processing and were being used initially. Only in 1998, two new varieties viz. Kufri Chipsona-1 and Kufri Chipsona-2 were released exclusively for processing, followed by Kufri Chipsona-3, Kufri Himsona, Kufri Chipsona-4 and Kufri Frysona in the years 2006, 2008, 2009 and 2010, respectively. In India potato is grown under short day conditions and cooler temperatures. The day length varies from 10 to 11 hours and the temperatures from 5 to 30°C. The potato crop receives about 370 hours of solar radiation and the productivity is 18.4 kg/ha/h. Thus the productivity of the potato crop in India is one of the highest in the world. Depending upon the variety, the dry matter content varies from 17 to 22%. Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chipsona-3, Kufri Chipsona-4, Kufri Himsona and Kufri Frysona have a dry matter content of more than 20%.

Because of the totally different agro-climatic conditions, the potato varieties developed under the European and American conditions do not perform well when grown under Indian conditions. Nine

Dutch varieties viz. Agria, Ajax, Anosta, Cardinal, Diamant, Fresco, Marfona, Sante and Desiree, two Frito-Lay hybrids viz. FL-1533 and FL-1625, developed by the American company Frito-Lay and one American variety viz. Atlantic were evaluated by the CPRI. Yield of these exotic varieties were lower than that of Indian varieties, when grown under Indian conditions.

The future varieties of potato meant for processing should yield between 25 and 30 t/ha, with a dry matter content of 22-23% and reducing sugar level below 150 mg/100 g fresh tuber weight, when grown for 90-100 days under short photoperiod (10-11h day length) and day and night temperatures of 25-30°C and 5-15°C, respectively.

Quantity and Quality of Potatoes Grown in Different Regions

Potato is grown in different parts of the country under diverse agro-climatic conditions. The potato growing areas in the country can be broadly classified into three zones i.e hills, plains and plateau.

5.1 Hills

The hill zone accounts for about 6.54% of the total potato production. In hills, the potato is grown on roughly 1,40,000 ha with an average productivity of 12-15 t/ha.

North-western hills: Hills of Himachal Pradesh (H.P.) accounts for most of the production in this region. In H.P., potato is grown from an elevation of 1000 to 3500 m above MSL. The major potato growing districts are Shimla, Mandi, Kangra and Lahaul and Spiti in H.P.

Summer crop is the main crop, which is planted in April and harvested in September (Table 3). Potatoes are grown under long days i.e a day length of up to 14 hour. The average maximum temperature during the crop season is 21.8°C and the minimum temperature is 15.2°C. Kufri Jyoti potatoes produced in Shimla contain dry matter ranging from 19-23% and the reducing sugar level is around 150 mg/100g tuber fresh weight.

Popular varieties: Upper hills of Himachal: Kufri Jyoti, Kufri Chandramukhi, Kufri Himalini.

Lower Hills of H.P.: Kufri Jyoti, Kufri Chipsona-1, Kufri Chipsona-3, Kufri Badshah, Kufri Pukhraj, Kufri Pushkar.

Uttarakhand Hills: In Uttarakhand hills, the potato is cultivated on an area about 13,600 ha, with an average yield of 9.8t/ ha. The potato growing districts of this region are Nainital, Almora, Pithoragarh, Dehradun, Tehri Garhwal, Uttar Kashi, Pauri Garhwal and Chamoli. Potato is grown here from 1,000 m up to 2,000 m above MSL.

The summer crop accounts for 80% of the potato crop in Uttarakhand hills. The crop is planted in March-April and harvested in August-September. The average maximum temperature during crop season is 21.5°C and average minimum temperature is 13.7°C.

Popular varieties: Kufri Jyoti, Kufri Chandramukhi

***North-eastern Hills*:** Potato is grown in an area of about 40,000 ha in the hills of North-eastern India spreading over six states. Of these, only in Meghalaya state the potato is grown on 18,450 ha with production of 1,81,820 metric tonnes and productivity of 9.86 t/ha. In the remaining states of this region, the area under potato varies from 1-10 thousand ha and the productivity levels are very low ranging from 5-13 t/ha.

The yields are generally higher in the summer crop planted in March and harvested in August than in the autumn crop grown during September- January. The average maximum temperature during crop season is 23.4°C and the average minimum temperature is 15.1°C.

Popular varieties: Kufri Jyoti, Kufri Megha, Kufri Himalini, Kufri Pukhraj, Kufri Kanchan, Kufri Giriraj.

Southern Hills: The Nilgiri and Palani hills constitute the Southrern hill region where potato is grown. In Nilgiri hills, potato is grown on 5,350 ha and the total production is 1,15,630t with 21.61 t/ha productivity. Though three crops can be grown in Nilgiri hills, the summer crop is the main crop which is planted in April and harvested in August. During the crop season, the average maximum temperature is 18.9°C and the minimum temperature is 12.2°C. Tubers of Kufri Jyoti grown at Ootacamund contain 22-23% dry matter and 118 to 229 mg reducing sugar/ 100g tuber fresh weight. Autumn crop is grown during September to December, but the area is much less than the summer crop. On a limited area, irrigated crop is grown from January to May.

Considering the limited area on which potato is grown in hills, it may not be possible to locate a potato processing plant in hill regions. The total quantity of potatoes available in the hills is not

adequate to sustain a processing plant. However, since hill potatoes come to market at a time when fresh potatoes are not available in plains, they can be utilized for processing in plains during these months. The prevalence of bacterial wilt in mid-hills and tuber moth in lower hills reduce the quality of tubers.

Nilgiri hills have a unique advantage of growing three crops in a year. That means fresh potatoes are available throughout the year. Unfortunately, the area under potato is very limited and the total quantity of potatoes produced in these hills is not sufficient to sustain a potato processing plant. Besides, the region is infested by cyst nematodes and therefore, the potatoes grown in Nilgiri can not be transported to others areas.

Popular varieties: Kufri Jyoti, Kufri Swarna.

5.2 Plains

About 90% of the crop is grown in sub-tropical plains of India. In plains potatoes are grown during winters when the temperature is mild and the days are short with the day length of about 10 hours. The crop generally matures in 90 days. However, late varieties may take upto 120 days to mature in some parts of the Indo-Gangetic plains.

North-western plains: Punjab, Haryana and Rajasthan constitute this zone. In Rajasthan the potato is grown on an area of 9,510 ha with a total production of 1,13,250 metric tonnes. Kota, Ganganagar and Bharatpur are the main potato growing districts of the state. Haryana has 30,000 ha under potato. The total production is 6,96,510 metric tonnes. Kurukshetra, Yamuna Nagar, Ambala and Karnal are the major potato growing districts of Haryana. In Punjab 87,240 ha area is under potato. The total production is 21,89,200 metric tonnes with an average yield of 25 t/ha. Jalandhar, Hoshiarpur and Ludhiana are the three major potato growing districts of the state. In this zone, Punjab accounts for around 80% of the total production. Three crops can be raised in this area i.e early, main and spring. The early crop which is planted in September is grown under high temperature conditions therefore, tuber initiation is delayed and yield is quite low. The lower yields are however compensated by the

high price that early potatoes fetch in the market. The early crop is produced for consumption as fresh potatoes and most of it is absorbed by the local market. Generally early crop is harvested immature. Therefore, it is not suitable for processing as immature potatoes contain low dry matter and high reducing sugars. The spring crop is planted late in January at low temperatures and harvested at high temperatures, in April/May (Table 3). This crop may be suitable for processing. The area under early and late potato crop is very small.

The main crop in this zone under short day condition is planted in the beginning of October and harvested in January/February (Table 3). The average maximum temperature during crop growth in Punjab is 24.6°C and average minimum temperature is 8.6°C. During the crop maturity period the average minimum temperature is as low as 4.5°C. Thus the potatoes grown in Punjab at low temperatures results in relatively low dry matter content and high reducing sugars. Potatoes of variety Kufri Jyoti grown in Jalandhar have a dry matter content ranging from 17.3 to 20% and reducing sugars content ranging between 202 to 370 mg/100g fresh weight. For this reason, potatoes grown in Punjab may not be suitable for processing purposes. However, processors do buy potatoes from some parts of Punjab for processing. In Haryana potatoes are grown under relatively low temperatures. The average maximum temperature during crop season is 27.5°C and the average minimum temperature is 9.7°C. Therefore, these potatoes may be suitable for processing. In some parts of Rajasthan potatoes are grown under warmer conditions. During the crop growth the average maximum and minimum temperatures are 29.1°C and 14.4°C, respectively, at Kota. Potatoes grown here can be expected to have higher dry matter and lower reducing sugar content. Therefore, these potatoes can be used for processing. However in Ganganagar area, the temperatures are low, therefore, potatoes grown here may not be suitable for processing.

Popular varieties:

Punjab- Kufri Jyoti, Kufri Pukhraj, Kufri Badshah, Kufri Pushkar, Kufri Sutlej, Kufri Anand, Kufri Surya, Kufri Chandramukhi, Kufri

Chipsona-1, Kufri Sindhuri, Kufri Khyati

Haryana- Kufri Jyoti, Kufri Badshah, Kufri Bahar, Kufri Sutlej, Kufri Pukhraj, Kufri Jawahar, Kufri Ashoka, Kufri Pushkar, Kufri Khyati.

Rajasthan: Kufri Jyoti, Kufri Lauvkar, Kufri Surya

North-central plains: Western U.P. and plains of Madhya Pradesh and Gujarat comprise this zone. Western U.P. is the major potato growing region in this zone where potato is grown in all districts. Most of the districts in this area produce more than one lakh tonnes. Meerut, Ghaziabad, Agra, Mathura, Aligarh, Firozabad, Mainpuri, Etah, Badaun, Muradabad, Farrukhabad, Kannauj and Etawah are some of the major potato growing districts of this area and all these districts have a productivity level of over 20 t/ha. As in Punjab, three crops can be raised in western U.P. also. The early crop planted around 15th September is mainly for the early market and is not suitable for processing. This crop is grown under high temperatures, which affects tuber initiation and yield. Lower yields of the early crop are compensated by the higher price these potatoes fetch in the local market. The early potatoes are harvested immature and therefore, with their uncured skins have poor keeping quality. Furthermore, because they are harvested immature they contain low dry matter and high reducing sugars, hence are not suitable for processing. The late crop is planted at low temperature and harvested at high temperatures, therefore, could be suitable for processing, but the area under late potatoes is negligible. The main crop in western U.P. is planted in the second fortnight of October and harvested in February (Table 3). The day length during crop growth varies from 10 to 11 hours. The average maximum temperature during crop growth is 25.5°C and the average minimum temperature is 11.1°C. During the crop maturity period, the average minimum temperature is 9.8°C. The night temperatures are not as low as in Punjab, therefore, the potatoes grown in western U.P. have relatively high dry matter content and low reducing sugar content. However, the minimum temperatures are not warm enough to produce potatoes highly suitable for processing. Kufri Jyoti potatoes grown in Modipuram contain dry matter ranging from 19.2 to 21.6% and reducing sugar may range from 135 to 274 mg/100g tuber fresh weight, whereas, processing varieties like

Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chipsona-3, Kufri Chipsona-4 and Kufri Frysona give dry matter 20 to 25% and reducing sugars between 30 to 140 mg/100g tuber fresh weight.

Madhya Pradesh (M.P.) has 1,10,000 ha under potato and the total potato production is 23,22,400 metric tonnes. In M.P., Indore is the major potato growing district. It has 20,124 ha under potato and 2,15,885 tonnes of potatoes are produced in this district alone with yield of 10.73 t/ha. Gwalior, Chhindwara, Tikamgarh, Shajapur, Ujjain and Dewas are some of the important potato growing districts of M.P. Gwalior district has an average maximum temperatures of 26°C and minimum temperature of 8.8°C during the crop season. These temperatures are comparable to those prevailing in western U.P. during the crop season. Therefore, potatoes produced in this district may not be comparable to those produced in other districts of M.P. so far as their processing quality is concerned. However, other districts of M.P. have temperatures that favour high dry matter and low reducing sugar content. For example, Indore district has average maximum and minimum temperatures of 27.6°C and 10.6°C respectively, during the crop season. The corresponding values of Raipur are 28.6°C and 14.7°C. Therefore, potatoes grown in the southern districts of M.P. have high dry matter and low reducing sugar content. Kufri Jyoti and Kufri Lauvkar are the two predominant varieties grown in this region and both these varieties are considered suitable for processing. Further, with the adoption of processing varieties, this region has become a hub of potato production for processing and practically all the processors procure good quality potatoes from this region. Potato is grown during October to February. After harvest in February, the potatoes are either stored for three to four months in heaps or under elevated temperatures in cold stores and thereafter supplied to the processors throughout the country.

In Gujarat, potato is grown on 73,640 ha with the production of about 22,67,380 metric tonnes of potatoes. Banaskantha, Sabarkantha, Kheda, Mehsana and Ahmedabad are the major potato growing districts which account for 90% of the state's production. Warm day temperatures and mild night temperatures during the crop season favour high dry matter production. Average

maximum and minimum temperatures at Deesa are 30.7°C and 11.9°C, respectively. The favourable minimum temperature helps in reduced accumulation of reducing sugars. Therefore, potatoes grown in Gujarat give the best quality for processing and the state is leading in production of processing grade potatoes as on date.

Popular varieties:

U.P.- Kufri Bahar, Kufri Pukhraj, Kufri Pushkar, Kufri Jawahar, Kufri Chipsona-1, Kufri Chipsona-3, Kufri Jyoti, Kufri Khyati, Kufri Sadabahar, Kufri Anand, Kufri Sutlej, Kufri Badshah, Kufri Ashoka.

M.P.- Kufri Lauvkar, Kufri Jyoti, Kufri Pukhraj, Kufri Badshah, Kufri Chipsona-1, Kufri Chipsona-3, Kufri Frysona, Kufri Surya

Gujarat- Kufri Lauvkar, Kufri Badshah, Kufri Chipsona-1, Kufri Chipsona-3, Kufri Pukhraj, Kufri Jyoti, Kufri Chandramukhi, Kufri Frysona, Kufri Surya

North-eastern plains: Eastern U.P., Bihar, Jharkhand, West Bengal, Assam and Odisha plains comprise this zone.

As we move from western U.P. towards the eastern Indo-Gangetic plains, the temperature during crop season increases. For example, Gorakhpur has a maximum average temperature of 25.4°C and the minimum of 11.9°C. While there is no appreciable change in the day temperature, the night temperatures increase slightly. The warmer night temperatures especially during maturity period (12.3°C) can be expected to result in higher dry matter and lower reducing sugar content. Potato is grown in all the districts of eastern U.P. and Varanasi, Barabanki and Faizabad are some of the major potato growing districts of this region.

Bihar with 3,18,500 ha area under potato are also major potato growing states in India. The total potato production is 65,35,000 metric tonnes and the productivity is 20.5 t/ha. Jharkhand with 49,100 ha area produces 6,53,100 metric tonnes of potatoes with the yield of 13.3 t/ha. Patna, Muzaffarpur, Nalanda, Rohtas and Samastipur are some of the major potato growing districts in Bihar. The temperatures prevailing during the crop season in Bihar are conducive for higher dry matter production. The average maximum

and minimum temperature during crop growth period at Patna are 25.9°C and 13.1°C, respectively. The corresponding values for Ranchi in Jharkhand are 24.7°C and 11.2°C, respectively. In Jharkhand, Ranchi has lower minimum temperature than Patna. Potatoes of variety Kufri Jyoti grown at Patna have a dry matter content ranging from 20 to 21%. The early crop is planted in September to October and harvested in December. The late crop is planted in November-December and harvested in March-April. The area under these two crops is low. The main crop is planted in October-November and harvested in February-March.

West Bengal has 4,12,300 ha under potato and produces 90,30,000 metric tonnes of potatoes with a productivity level of 22 t/ha. Three districts viz. Hooghly, West Midnapur and Burdwan together account for 76% of the state's production. Jalpaiguri, Howrah and Morshidabad are the other districts that produce considerable quantity of potatoes. The average maximum and minimum temperature at West Midnapur during the crop season is 28.1°C and 12.3°C, respectively. As in Bihar, the temperatures are quite conducive for high dry matter production and we can expect dry matter content comparable to that in Bihar. The main crop is planted in October-November and harvested in February-March. The high productivity, higher dry matter and lower reducing sugar content that can be expected are all favourable points for the potato processing industry. West Bengal is likely to witness increased activity in potato processing.

Assam has 98,000 ha under potato and produces 7,00,100 metric tonnes of potato. Barpeta, Kamrup, Dhubri, Darrang, Dhemaji, Udalguri, Nagaon and Sonitpur are the major potato producing districts of Assam. The main crop is planted in November and harvested in February-March. During the crop season the maximum and minimum temperature are 26.6°C and 13.9°C, respectively. The plains of Assam have minimum temperatures that are slightly higher than West Bengal during crop season and as a result higher dry matter content can be expected in potatoes grown in this region.

Odisha has 14,990 ha under potato and produces 2,49,760 metric tonnes of potatoes which amounts to 0.6% of the country's production. Cuttack, Puri and Kendrapara are the major potato

producing district in this state. The average maximum and minimum temperatures during the crop season at Cuttack are 29.7°C and 17°C, respectively. Since the temperatures are quite conducive, this region can be expected to have high dry matter content. The higher minimum temperatures do not favour accumulation of reducing sugars. Therefore, low reducing sugar content can be expected in the potatoes produced in Odisha.

Popular varieties:

Bihar & Jharkhand- Kufri Sindhuri, Kufri Jyoti, Kufri Pukhraj, Kufri Khyati, Kufri Ashoka, Kufri Chandramukhi, Kufri Lalima, Kufri Arun

West Bengal-Kufri Jyoti, Kufri Chandramukhi, Kufri Pukhraj, Kufri Himalini, KufriAshoka, Kufri Jawahar,Kufri Anand, Kufri Chipsona-1, Kufri Chipsona-2.

Assam- Kufri Jyoti, Kufri Pukhraj, Kufri Himalini

Odisha - Kufri Jyoti, Kufri Pukhraj, Kufri Ashoka, Kufri Lauvkar, Kufri Chipsona-1

5.3 Plateau Region

The plateau region consists mainly of Maharashtra and Karnataka. Parts of Chhattisgarh and Odisha are also included in this region.

Maharashtra, with an area of 20,000 ha under potato, produces 3,70,000 metric tonnes of potatoes with an average yield of 18.5 t/ha. Pune, Satara, Latur and Nasik are the main potato growing districts. Together they account for 85% of the state's production. Two crops can be raised in this region (Table 4). The *kharif* crop is planted in June-July and harvested in September-October. This is a rain-fed crop and the average maximum and minimum temperatures during the crop season are 27.8°C and 21.4°C, respectively. Since this is a rain-fed crop, the dry matter content of potatoes is relatively lower than the potatoes produced during *rabi* season. The second crop is the *rabi* crop which is irrigated. This crop is planted in November and harvested in January-February. The average maximum temperature during the crop season is 31.1°C and the average

minimum temperature is 13.1°C. Potatoes harvested from the *rabi* crop have high dry matter and low reducing sugar content. Potatoes produced at Rajgurunagar during the *rabi* season are known to contain higher dry matter when compared to those grown in the Indo-Gangetic plains and northern hills. A dry matter content of 21% and above is common in potatoes produced in this region. Low reducing sugar content can be expected in these potatoes.

Karnataka produces 5,39,700 metric tonnes of potatoes from 40,710 ha area. Hassan, Belgaum, Dharwad, Kolar and Bangalore are the major potato growing districts. Two crops are raised here also. The *kharif* crop is rain-fed. It is planted in June-July and harvested in September-October. The average maximum and minimum temperatures during the crop season at Hassan are 25.7°C and 19°C, respectively. The *rabi* crop, which is irrigated, is the main crop in this state. The production during the *rabi* season is much more than that in *kharif*. The average maximum temperature at Hassan during the *rabi* season is 29.1°C and the average minimum temperature is 16.2°C. Similar temperatures prevail at Belgaum and Bangalore and these temperatures are conducive for high dry matter production. The favourable minimum temperature should reduce the accumulation of reducing sugars in potatoes grown in this region.

Popular varieties:

Maharashtra- Kufri Lauvkar, Kufri Jyoti, Kufri Pukhraj, Kufri Himalini, Kufri Chadramukhi, Kufri Surya

Karnataka- Kufri Himalini, Kufri Jyoti, Kufri Pukhraj, Kufri Surya

Table 3: Potato Crop Calender

Zone	Crop season	Planting time	Harvesting time
HILLS			
North-western hills and Uttarakhand			
High hills	Summer	April	September
Mid hills	Autumn-winter	August/September	March/April
North-eastern hills			
	Summer	March	August
	Autumn	August/ September	December/ January
Southern hills			
	Summer	April	August
	Autumn	September	December
	Winter	January	May
PLAINS			
North-western plains			
	Autumn (early)	September	November/ December
	Autumn (main)	October	January/ February
	Spring	January	April/May
North-central plains			
	Autumn (early)	September	November/ December
	Autumn (main)	October	February
	Spring (late)	November/December	March/ April
PLATEAU			
	Kharif	June/July	September/ October
	Rabi	November	January/ February

Table 4 : Zone-wise popular potato varieties of the country

Zone	Season	Varieties
North Western plains	Early	Kufri Ashoka, K. Chandramukhi, K. Pukhraj, K. Gaurav, K. Khyati, K. Jawahar, K. Lauvkar
	Medium	Kufri Anand, K. Arun, K. Badshah, K. Chipsona - 1, K. Sadabahar, K. Chipsona - 3, K. Pukhraj, K. Pushkar, K. Surya, K. Jyoti, K. Bahar, K. Sutlej, K. Chipsona-1
	Late	Kufri Sindhuri
North Central Plains	Early	Kufri Chandramukhi, K. Gaurav , K. Ashoka, K. Jawahar, K. Khyati, K. Lauvkar
	Medium	Kufri Arun, K. Anand, K. Badshah, K. Bahar, K. Chipsona-1, K. Chipsona - 3, K. Pukhraj, K. Pushkar, K. Surya, K. Frysona, K. Sadabahar, K. Jyoti, K. Sutlej
	Late	Kufri Sindhuri
North Eastern Plains	Early	Kufri Ashoka, K. Chandramukhi, K. Gaurav , K. Khyati, K. Lalima, K. Jawahar, K. Lauvkar
	Medium	Kufri Anand, K. Arun, K. Chipsona-1, K. Chipsona-2, K. Chipsona-3, K. Pushkar, K. Surya, K. Bahar, K. Jyoti, K. Kanchan, K. Chipsona-4, K. Pukhraj, K. Himalini,
	Late	Kufri Sindhuri
Plateau & Central Plains	Early	Kufri Chandramukhi, K. Lauvkar
	Medium	Kufri Pukhraj, K. Badshah, K. Chipsona - 1, K. Chipsona - 3, K. Surya, K. Lauvkar, K. Jyoti, K. Chipsona-4, K. Himalini
North-Western Hills	Early	Kufri Chandramukhi
	Medium	Kufri Giriraj, K. Himalini, K. Jyoti, K. Shailja, K. Himsona, K. Girdhari, K. Chipsona-1, K. Chipsona-3, K. Badshah, K. Pukhraj, K. Pushkar
North Eastern Hills	Medium	Kufri Giriraj, K. Himalini, K. Jyoti, K. Megha, K. Shailja, K. Girdhari, K. Pukhraj, K. Kanchan
North Bengal & Sikkim Hills	Medium	Kufri Jyoti, K. Kanchan
Southern Hills	Medium	Kufri Giriraj, K. Himalini, K. Jyoti, K. Shailja, K. Swarna, K. Girdhari

Plains: Early = 70-90 days, Medium = 90-110 days, Late= > 110 days

Hills: Early = 100-110 days, Medium = 110 -120 days, Late = > 120 days

(Source: Agro-Techniques for Production of Quality Potato Seed, Extension bulletin no. 43, CPRI, Shimla)

Areas Suitable for Producing Processing Potatoes

Potatoes are grown in almost all agro-ecological zones in the country and different varieties are used in these zones depending on their productivity. Major quantity of potatoes is meant for consumption as table potatoes and is not suitable for processing. Dry matter and reducing sugars are the two parameters that are of utmost importance to the potato processing industries as described earlier. Although both of these traits are characteristics of a variety, but different environmental and agronomic conditions such as temperature during crop growth, day length, light intensity, soil type, availability of moisture, time of irrigation, rainfall, tuber maturity, etc. affect these traits. Out of all these parameters, temperature plays a major role in the dry matter and reducing sugars accumulation. Night temperature of 10°C or more during the last 30 days of crop growth improves the quality of the potatoes and produces potatoes with high dry matter and low reducing sugars. Areas suitable for potato processing in different parts of the country have been identified based on the temperatures during the later phase of crop growth. Generally crop grown in the eastern and the southern parts of the country contain high dry matter and low reducing sugars.

The potato growing areas in the country can be broadly classified into three categories viz. least suitable, suitable and most suitable for growing processing potatoes (Figure 11). This classification has been made based on the average minimum temperatures prevailing during the crop season and during the last 30 days of crop growth in the field. Generally a dry matter content of 18-20% is considered acceptable for processing potatoes into chips. We can expect a dry matter content of 18-20% when the average minimum temperature is between 10 and 12°C, which is the case in most parts of Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, Madhya Pradesh, Gujarat and North-eastern hills states. The area, marked green in the map, is suitable for growing processing potatoes. When the average minimum temperature is more than 12°C, we can expect a dry

matter content of 20% and more, and a low level of reducing sugars. The areas marked yellow, which includes the entire plateau region and most of the North-eastern plains and a part of Gujarat, Rajasthan and M.P. falls in this category. Even within a state, there could be variations. For example, in Rajasthan the areas around Kota have higher minimum temperatures during crop growth, therefore, the potatoes grown here can be expected to be most suitable for processing. On the other hand, the areas around Ganganagar have low night temperatures prevailing during the crop season. The region marked blue comprising Punjab, Haryana, Delhi and the adjoining area of western U.P. may not be suitable for growing processing potatoes. As far as dry matter is concerned the projections made in the map are correct, however, in case of reducing sugars, levels may vary and could reach unacceptable levels in some of the green areas bordering the blue region.

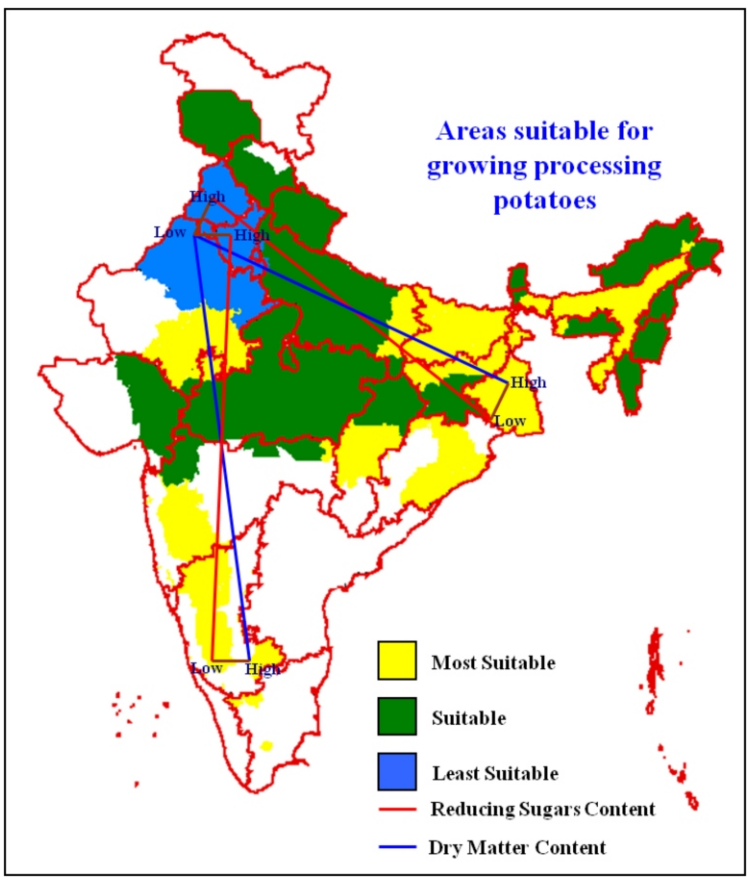


Figure 11: Areas suitable for growing processing potatoes in India

Only temperature has been taken into account since temperature is the dominant factor in the effect of location on dry matter and reducing sugar content of potato. However, there could be other environmental factors that influence these two quality parameters. For example, in the case of hills in north and north-eastern regions, though the minimum temperatures are favourable for high dry matter production, because of high rainfall conditions under which the crop is raised, the potatoes produced here contain less than 20% dry matter. For this reason, the hilly areas have been included in the green zone. Similarly, in the plateau region the *kharif* potato which is grown under rain-fed conditions will contain relatively less dry matter than the *rabi* potatoes.

The projection based on the map is meant to give a broad guideline to those interested in potato processing. It is always advisable to get the potatoes tested for their dry matter and reducing sugar contents to make sure that the potatoes are suitable for processing.

Table 5: Recommended states for growing processing potato varieties

Variety	States
Kufri Chipsona-1	Bihar, Punjab, Rajasthan, Gujarat, U.P., West Bengal, Delhi, Haryana, H.P., Jammu & Kashmir
Kufri Chipsona-3	Bihar, Punjab, Maharashtra, Gujarat, Rajasthan, U.P., West Bengal, Delhi, Haryana, H.P., Jammu & Kashmir
Kufri Chipsona-4	M.P., West Bengal, Karnataka, Maharashtra, Gujarat
Kufri Himsona	H.P., Jammu & Kashmir, Uttarakhand, Arunachal Pradesh, Assam, Manipur, Meghalaya, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Gujarat, M.P., Chattisgarh, Bihar, Rajasthan, Mizoram, Nagaland, Sikkim, Tripura, West Bengal
Kufri Frysona	Bihar, Punjab, Gujarat, Rajasthan, U.P., West Bengal, Delhi, Haryana, H.P., Jammu & Kashmir
Kufri Jyoti	H.P., Jammu & Kashmir, Uttarakhand, Andhra Pradesh, Karnataka, Tamil Nadu, Bihar, Punjab, Rajasthan, U.P, , West Bengal, Delhi, Haryana, Gujarat, M.P., O disha, Chhattisgarh, Kerala, Maharashtra
Kufri Chandramukhi	Bihar, Punjab, Rajasthan, U.P., West Bengal, Delhi, Haryana, H.P., Jammu & Kashmir, Tamil Nadu, Karnataka, Gujarat, M.P., Odisha, Chhattisgarh, Kerala, Andhra Pradesh
Kufri Lauvkar	Tamil Nadu, Karnataka, Gujarat, M.P., Odisha, Chhattisgarh, Kerala, Andhra Pradesh, Rajasthan, U.P., Bihar, Maharashtra

(Source: National Horticulture Board, Indian Horticulture Database-2013)

Availability of Fresh Potatoes for Processing

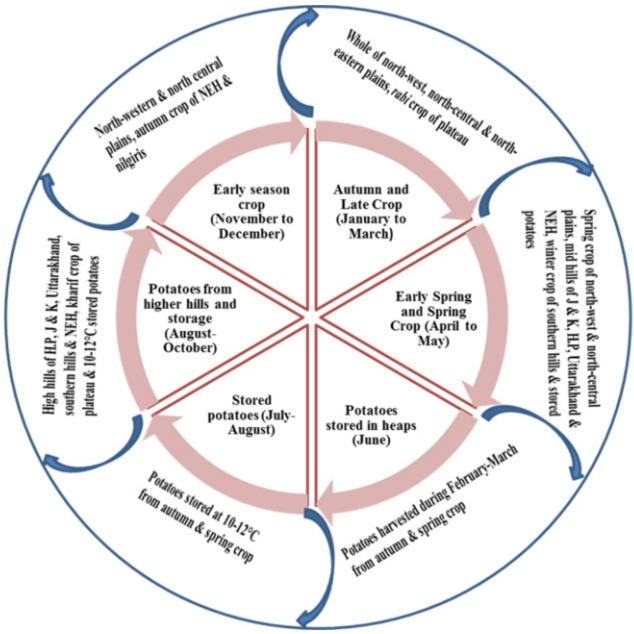


Figure 12: Availability of fresh and stored potatoes for processing

7.1 Distribution and movement of potato within the country

From the point of view of the distribution and movement of potatoes within the country, the pattern of its production in different zones is very important. The produce is available at different times in different zones (Table 6). This provides an opportunity for its distribution and movement from the production areas to the consumption areas. This has led to the development of various channels of potato movement within the country. Apart from the inter-regional distribution, two main types of movements are (i) from the northern plains to other plains and plateau areas and (ii) from the northern hills to the plains.

Since most of the production of potatoes in the country is in the northern plains and hills, the distribution and movement of potatoes from these regions is of special importance in ensuring the

availability of potatoes for the major part of the year. The early crop is lifted in immature stage, and is moved immediately to the consuming centers to avail high prices. Part of the main crop which is harvested after maturity is moved immediately and rest of the produce is stored in the cold stores spread over the country, to meet the requirements of the consumers in the later part of the year. In some areas a late crop is taken in spring and is harvested at a time when the temperatures in the plains of India starts rising, and has a poor keeping quality. Therefore it is disposed off immediately. This is followed by the immature produce from the mid-hills and is supplemented with the supplies from the cold stores. This continues till potatoes from the high hills become available in the months of September-November, completing the cycle.

In addition to the movements of potatoes within the northern region, considerable quantities are transported to the consuming centers in the peninsular India, where the local production from the rainy season and winter crops falls short of the requirements.

Arrival of potatoes in the major markets of India is the maximum between January and May and more or less evenly distributed through the remaining months. The table makes it clear that potatoes are available in adequate quantity throughout the year. The point of concern for the processor is however, the fact that during summer months and until October considerable quantity of potatoes from cold stores arrives in the market which usually have high reducing sugars content.

Table 6: Periods and sources of arrival of potatoes in market in India

Period	Source	Availability of fresh potatoes
January-May	Uttar Pradesh, Bihar, West Bengal, Punjab, Madhya Pradesh, Assam, Karnataka, Haryana, Maharashtra, Odisha, Gujarat.	High
October-December	Punjab, Uttar Pradesh, Mid & Low hills	Low
May-June	Spring crop in hills, and North - western plains	Low
September-October	Northern high hills and valleys and plateau areas	Low
July-August	Southern hills	Low
December-January	Southern hills	Low

7.2 Prices and arrivals of potato

A number of factors determine the price of potatoes. The foremost is the yearly production and availability of the produce, followed by the distance and size of the market in the consuming centers. Last but not the least is the effect of facilities for storage on the prices.

Over the past few years, the retail prices of potatoes has been increasing steadily, perhaps in synchrony with the general price rise of agricultural commodities. This has happened inspite of the fact that the total production of potato in the country has been showing a gradual increase. In general the long time trend of the price has been governed by the law of supply and demand. Generally, the prices of immature crops are very high, gradually decreasing till the main harvest, when they are lowest in the year. But after a few weeks, the prices tend to rise and remain high till the end of the year (Table 7).

Prices in general are lower in the production centers than in the consumption centers. For example, the prices of potatoes in Mumbai, Madras and Bangalore are higher than those in production centers like Agra, Amritsar and Jalandhar during January and February. Prices of potato in production and consumption centers with large cold storage capacities are much lower than in areas where cold storage capacities are rudimentary. Potato prices remain high between May and November throughout the country.

Table 7: Average wholesale, retail price and total arrival of potato in 2015

Month	Wholesale Average Price (Rs./q.)	Retail Average Price (Rs./q.)	Total Arrival (Metric tonnes)
January	1019.346	1576.808	8618.231
February	890.115	1401.692	7756.385
March	723.962	1233.154	8330.000
April	702.846	1173.500	7764.846
May	661.154	1077.615	7014.962
June	617.154	1002.769	5439.154
July	567.346	909.539	4883.308
August	617.808	1015.269	5249.577
September	597.923	966.000	4871.615
October	652.5	1037.808	4733.885
November	752.962	1206.231	5609.500
December	860.269	1406.692	7113.538

Values given are the average of twenty six major markets in India

(Source: Month-wise annual price and arrival report, National Horticulture Board.)

Delhi is the biggest market for potatoes because of its proximity to the producing centers in western U.P., Punjab, Haryana and the hills of Himachal Pradesh and Uttarakhand. Next to Delhi, Kanpur is the biggest market for potatoes. Most of the potatoes of the central and eastern parts of U.P. come to Kanpur market. Mumbai is the third biggest market in the country. Wholesale prices of fresh potatoes in mega cities are given in Figure 13. The large arrivals in Mumbai during December and January when no fresh potatoes are available in the plateau region are indicative of the large movement of potatoes from the northern plains to Mumbai. While the arrivals in big market like Delhi and Kanpur are consistent throughout the year. Large quantities of potatoes arrive between December and March, and much less between May and November (Figure 14).

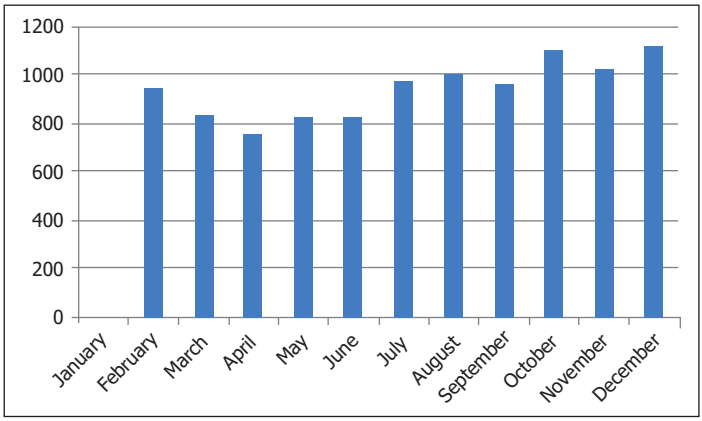


Figure 13: Wholesale price of fresh potatoes in the year 2015 (Rupees/quintal) in mega cities (Average of Delhi, Mumbai, Kolkata and Chennai)

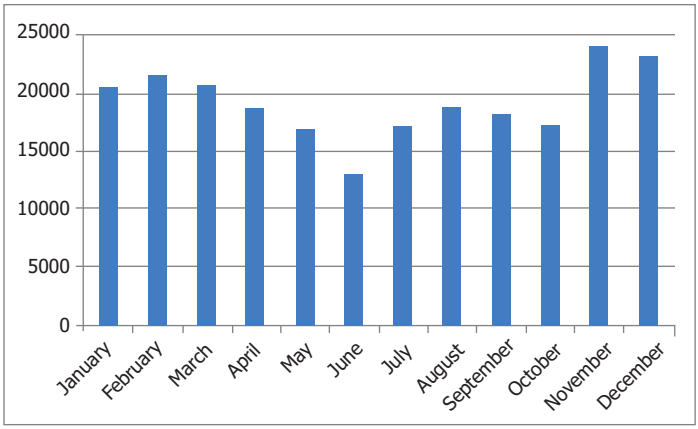


Figure 14: Arrival of fresh potatoes in the year 2015 (Metric Tonnes) in mega cities (Average of Delhi, Mumbai, Kolkata and Chennai)

7.3 Possibilities for improving the availability of processing potatoes

Potatoes grown in plateau, north eastern and north western hills are suitable for processing, but the productivity of potatoes in these areas is quite low compared to national average yield of 21t/ha. If the yield in these areas could be increased to the level of national average, a large quantity of processing grade potatoes would be available for processing.

Variety is an important factor which affects the processing quality of potatoes. ICAR-CPRI has released six processing varieties by now viz. Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chipsona-3, Kufri Chipsona-4, Kufri Himsona and Kufri Frysona. Most of the processors are utilizing these cultivars for processing them into various products due to their low reducing sugars and high dry matter content. Besides, some exotic varieties viz. Lady Rosetta, Atlantic, FL 1533, etc. are also being grown under contract farming by the organized processors for their use in making potato chips. Similarly, for French fries and frozen potato products, varieties like Kennebec, Shepody, Innovator, Santana, etc. are being cultivated using contract farming system. This trend is bringing more and more area under processing potatoes and is expected to grow further.

On the other hand, ICAR-CPRI is continuing breeding programme for the development of short duration processing varieties and with the release and adoption of such varieties it would be possible to grow processing potatoes in non-traditional areas as well. The farmers have been realizing better remuneration from processing varieties even if they are sold to table market, therefore, now there is an inclination of the potato producers towards cultivation of processing varieties. Such trend is highly positive for increased availability of raw material for processing. The storage technology using elevated temperature storage has been perfected and is consistently being adopted by more and more number of cold storages. This in itself is able to provide good quality raw material to the industry for few months.

All the above trends show possibility of increase in the availability of processing grade potatoes in the country for meeting the expected growth rate in processing sector.

Transport and Storage of Potatoes for Processing

8.1 Transport requirement

Potatoes are generally transported in railway wagons or lorries. These are uninsulated and often left to the vagaries of the weather during transit. Quite often, wagons are left in sidings where the bags are exposed to very high temperatures during the summers. The entire consignments are known to have rotted under such conditions. In order to avoid such situations there is need to have specially designed railway wagons with improved ventilation. The railways can run superfast potato specials between the potato producing and consuming regions. Lorries are the main mode of transport for potatoes. Even these potatoes are exposed to the vagaries of the weather, though for much shorter period. Use of padding materials during long distance transport is also recommended for maintenance of keeping and processing quality in potatoes, besides the policy issue of developing cold chains for transport of potatoes.

8.2 Potato storage methods

Most of the potatoes in India are harvested in February-March in the Indo-Gangetic plains when the temperatures begin to rise and thus, they have to be stored during the hot summer months. The storage method depends on the required duration of storage and destined use of potatoes and it can be broadly divided into two categories viz., refrigerated storage and non-refrigerated storage.

Refrigerated storage

Refrigerated storages are generally used for long-term storage of seed and ware potatoes. This is essentially done in commercial cold storages since potatoes harvested in February-March have to be stored until October or so for 6-8 months (Figure 15).

Storage at 2-4°C

There are roughly 7000 cold storages in India with approximate capacity of 31 million metric tonnes and of the total capacity of cold

stores, approximately 80% is used for storage of potatoes alone. Low temperature storage is the most common method of potato storage in the country. Low temperature storage is effective because at storage temperature of 4°C and below, sprout growth does not take place in most of the varieties. Further, the metabolic processes are slowed down therefore; losses caused by respiration are the minimum. In India, cold stores were developed mainly for the storage of seed potatoes but the present utilization pattern of cold storage space in different parts of the country shows that about 60% of the cold storage space is being used for the storage of ware potatoes and 40% for the storage of seed potatoes. Since the primary purpose of storage at 2-4°C is to check sprout growth, storage of seed potatoes at 2-4°C in cold store is ideal. But storage of ware potatoes at 2-4°C is not desirable since low temperatures induce accumulation of large amounts of sugars making the tubers sweet and therefore, less suitable for consumption. Besides, the cold stored potatoes are unfit for processing as high level of reducing sugars causes browning in potato chips, even the keeping quality of cold stored potatoes deteriorates quickly once they are removed from the cold store as tubers begin to sprout fast and marketing of cold stored potatoes is also a problem, due to their poor keeping quality. The high sugar content of potatoes stored at 2-4°C can be reduced to some extent by reconditioning at 20°C for up to 6 weeks. However, reconditioning cannot restore the sugars to the initial levels. Therefore, it is recommended that 2-4°C storage be used for seed potatoes only and the potatoes meant for table and processing should be stored at higher temperatures either under elevated temperatures of 10-12°C for long-term (6-8 months) or under non-refrigerated conditions for short-term (3-4 months).

Figure 15: A traditional cold storage and stack of potatoes inside the store

Elevated temperature storage at 10-12°C

Potatoes for ware and processing purposes are generally stored at 8-10°C in the developing world. This storage temperature does not allow excessive sugars accumulation, therefore, potatoes are not sweet in taste. Since sugar level is within the acceptable limit, the potatoes are also suitable for processing. But this temperature does not slow down sprout growth at the release of dormancy and therefore, some sprout suppressant has to be used for checking sprout growth. CIPC (isopropyl N (3-chlorophenyl) carbamate) is the most common sprout suppressant used on potatoes. It is a mitotic inhibitor and checks sprout growth by inhibiting cell division. This chemical was registered for use in India only in 1998, and at present (2015) about 625 cold stores in the country are using this chemical on potatoes stored at 10-12°C (Figure 16).

Figure 16: A commercial cold store using 10-12°C storage technology, potatoes stored in leno bags and comparison of chip colour from two refrigerated storages

Non-refrigerated storage of potatoes

The infrastructure for refrigerated storage in the country is unevenly distributed and sometimes it is beyond the reach of small and marginal farmers. In many states the storage facility is either lacking or is not adequate to accommodate the ware/ seed potatoes. Many farmers in these states use indigenous storage practices like pits, heaps, trenches and basements to hold some of their produce for short-term to fetch better prices during off-season. Though these on-farm storage methods are economical and practical, they are not efficient because of higher losses due to increased rotting (10-21%). Therefore, improvements were done in the traditional storage practices, particularly, potato heaps as a part of marketing strategy to increase remunerations from potato cultivation by holding the produce on-farm for short periods (3-4 months) and to bypass the

immediate post-harvest period when the prices are the lowest (Figure 17).

Improved heaps help to reduce the daily range of variation in temperatures while maintaining a high relative humidity (RH). While the day time variation in ambient temperature and relative humidity is considerable, the atmosphere inside the heap is quite stable. Minimum-maximum temperatures in the heap during storage (March to June) ranges between 13-30°C as compared to 8-44°C of the ambient and RH remains consistently high (60-95%) compared to wide variation and lower levels (27-87%) of the ambient as observed during experimentation. Weight loss and rottage are significantly reduced (<10%) in potatoes stored in heaps as compared to those stored at room temperature. Weight loss up to 10% is considered acceptable because no visible shrivelling takes place up to this level, the stored potatoes remain firm and desprouted potatoes fetch prices comparable to the cold stored potatoes, which are 40-50% higher than that at the time of harvest. Treatment of potatoes with sprout suppressants before heap storage has been found to reduce the losses further.

Physiological and pathological losses in potatoes are higher under non-refrigerated conditions, therefore, appropriate pre and post-harvest measures are to be strictly followed for successful storage in heaps as described previously. Storage in heaps may be completed by the end of February so that the lower temperatures prevailing during this period can be taken advantage of. Heaps may be protected from unseasonal rains either by erecting a thatched roof or covering with a water proof sheet. If a water proof sheet is used, it needs to be removed after the rain stops. Stored potatoes may be sent to the market before the temperatures inside the heaps reaches 30°C.

Potatoes stored in heaps are highly suitable for processing due to low reducing sugar content. These are also not sweet in taste and are more preferred as table potatoes. Therefore, the prices fetched by these potatoes in markets as table potatoes are also more than the cold stored potatoes.

Figure 17: A modified heap and potatoes after removal (treated with CIPC)

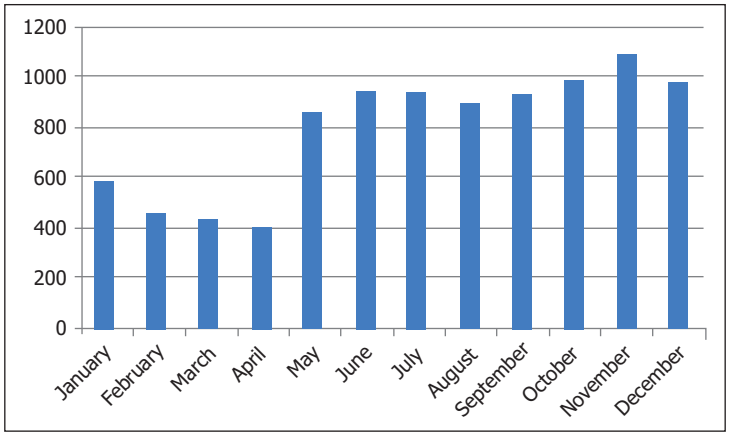


Figure 18: Wholesale prices of stored potatoes in the year 2015 (Rupees/quintal) in mega cities (Average of Delhi, Mumbai, Kolkata and Chennai)

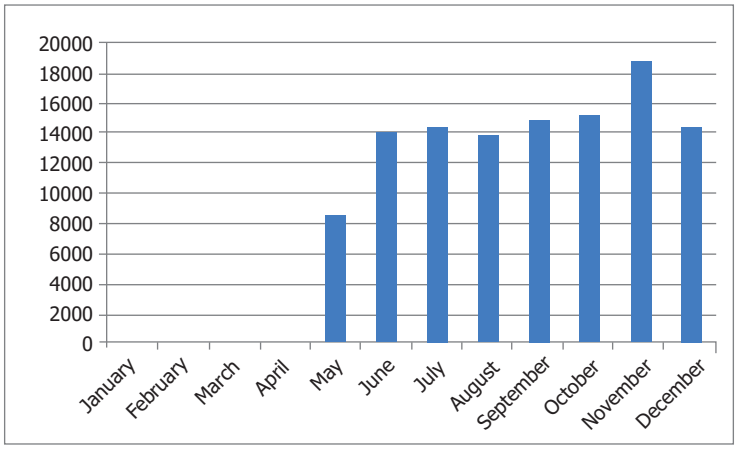


Figure 19: Arrival of stored potatoes in the year 2015 (Metric ton) in mega cities (Average of Delhi, Mumbai, Kolkata and Chennai)

8.3 Reconditioning of cold stored potatoes

The increase in the sugar content of cold stored tubers can be reversed to some extent by a process known as reconditioning. Potatoes stored at low temperatures are transferred to 15-18°C for about 2 weeks. At this temperature, a part of the sugar is used up in the synthesis of starch, thus resulting in potatoes which are more acceptable for frying than those from the cold stores (Figure 20 & 21). However, this process also has some drawbacks. Cold stored potatoes, when transferred to high temperatures are likely to lose moisture and hence weight loss is expected in those potatoes. Additionally, the potatoes are prone to sprouting as their rest period is already over. Moreover, all lots of cold stored potatoes may not recondition satisfactorily.

90 DOS at 4°C **90 DOS at 4°C+Recond (15d) at 20°C**

Figure 20: Potato chips prepared from Kufri Chipsona-2, without and with reconditioning of potatoes (DOS : days of storage, d: days)

90 DOS at 4°C **90 DOS at 4°C+Recond (15d) at 20°C**

Figure 21: French Fries prepared from Kufri Frysona without and with reconditioning of potatoes (DOS : days of storage, d: days)

Practical aspects of Potato Processing

For the production of potato products of uniform quality, a number of operations have to be performed as listed below:

I. Grading
II. Cleaning
III. Peeling
IV. Cutting/slicing
V. Blanching and cooling
VI. Surface drying
VII. Frying or dehydration
VIII. Cooling
IX. Sterilization (for canned potatoes only)
X. Packaging

Grading: Grading is generally done based on the requirement of the processor for the product. For instance, the producer of French fries requires potatoes of large size, but for canning one would prefer small sized potatoes so that they can be canned as it is. Most of the farmers in India sell ungraded potatoes, and even the wholesalers rarely grade potatoes. However, in some places the wholesalers and the retailers do carry out a rough grading, into large, medium and small potatoes. This grading is generally done by hand and is largely subjective, depending mainly on the person carrying out the operation. For the processor of French fries and chips, grading has to be more stringent so that the processor can use most of the potatoes of a lot for the product. Grading can be done with riddles or with mechanical graders which have large capacities (Figure 22 & 23). During grading damaged and green potatoes are also removed.

Figure 22: Grading of potatoes manually and through grading sieve

Figure 23: Mechanical grading of potatoes

Cleaning: During harvesting and transport of potatoes from the field, quite often stones and clods find their way with the potatoes. These have to be removed before grading is done either manually or mechanically. At the plant, cleaning of potatoes involves removal of adhering soil and washing with water. Washing is also done after peeling, slicing or cutting of potatoes into desired sizes. This is done to remove starch from the cut surfaces.

Peeling: Peeling is done to remove the skin. While in the freshly harvested immature potatoes, the skin is very soft and can be removed fairly easily, peeling of mature potatoes calls for a little stronger measure. Peeling is done mainly with abrasive peelers (Figure 24). Abrasive peelers are available for either batch or continuous peeling. The aim of peeling should be to ensure removal of at least 80-90 percent of the skin without removing too much of the flesh of the potatoes.

Figure 24: An abrasive potato peeler

Cutting/Slicing: Potatoes are cut into pieces of different sizes depending upon the product to be prepared. In the case of potato chips, the slices should be uniform and have smooth surface to avoid differences in colour and moisture content. Thicker slices do not fry properly. Slicing should be done with sharp knives, as use of blunt knives may result in damaging many cells and causing greater loss of dry matter (starch) in washing the slices. For chips and French fries preparation, manual and electrical slicers are available in market (Figure 25 & 26).

In order to produce potato chips or French fries of uniform size, ends and sides of potatoes are unfit, but these can be used for preparation of dehydrated products, or other ready to serve products.

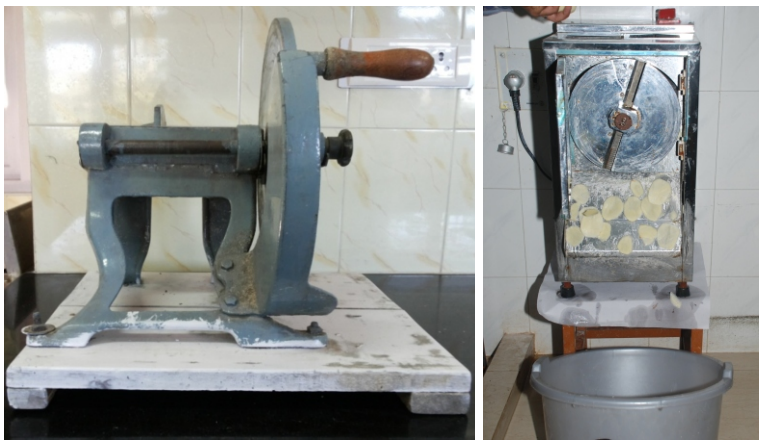


Figure 25: Manual and electrical potato slicer for making chips

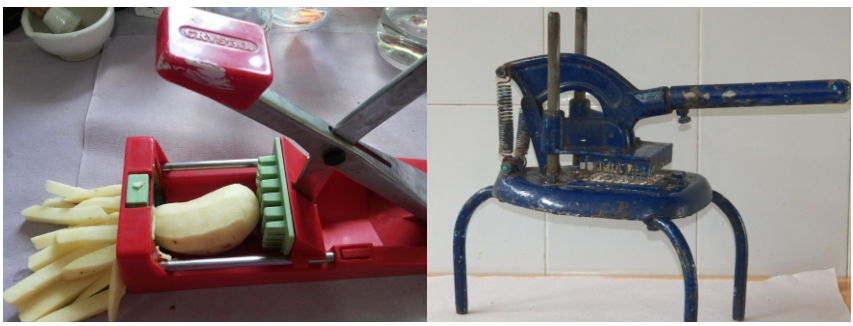


Figure 26: Manual potato cutter for making French fries

Blanching/Cooking: Blanching is carried out to inactivate some of the enzymes, and in case of chips and French fries, sometimes to remove excess sugar from the surface of the chips or the French fry, resulting in a uniformly desirable colour of the product. Blanching is generally done with steam for about 2-3 minutes, so that the surface layers of the chips and French fries are not cooked. Blanching can be done in blanchers (Figure 27) as well as large utensils.

Blanched products should be cooled quickly by either spraying cold water or by blowing cold air over the slices or the strips. Potatoes have to be cooked for the production of dehydrated products such as flakes or granules. Cooking can be done using batch type cookers (like pressure cookers) or in continuous operations.

Figure 27: Blanching of potato slices for making chips

Surface drying: After blanching, slices/sticks should be partially dried to remove excess moisture from the surface. For this purpose spin dryers can be used that works on principle of centrifugal forces (Figure 28).

Figure 28: Spin dryer with potato chips

Frying: Most popular fried potato products are potato chips and French fries. Frying aims at removing most of the moisture from potato chips which contain only about 1-2% moisture. The resulting chips should be golden in colour and crunchy. Whereas the French fries, which contains a substantial amount of moisture should have a uniform golden colored crust but should be soft yet cooked inside. Both the chips and French fries should not be oily or greasy. For frying, electrical fryers are preferred with digital display (Figure 29).

Figure 29: Electrical fryer

Selection of the frying medium is very important. It should not impart any colour or flavour to the fried products and should be stable at the temperatures used for frying. Because of the increasing concern for human health fats and oils such as lard, coconut or palm oils are no longer used. Blends of soybean oil and canola are often the preferred medium of cooking. Cotton seed oil or corn oil can also be used. The life of the cooking medium can be prolonged by removing the moisture on the surface of the chips or French fries.

Dehydration: Potato flakes, granules and dehydrated dice are the popular forms of dehydrated potatoes. Dice can be dried in batches in tray driers or continuously on belt type driers.

Potato flakes are dried on drum driers. Cooked potatoes are mashed, and a portion of the flakes is added to the mash to reduce the moisture content. The resulting material is applied to the drums of the drum driers.

For the preparation of granules also the add back process is used. A portion of granules is added to mash. The resultant mass is dried using a fluidised bed drier.

Cooling/Freezing: Fried or dehydrated products are rapidly cooled using cold air and deep freezers (Figure 30). World over, a large proportion of the French fries are transported and sold in frozen condition. Cooked French fries are individually frozen using a belt type freezer.

Figure 30: Deep freezer and frozen French fries

Sterilization: Canned potatoes are usually sterilized. Sealed cans are sterilized at a pressure of 10 pounds per square inch (psi) for 45 minutes.

Packaging: Various types of packaging materials are used by the industry. Chips and French fries can be packed in laminated packing materials which prevent entry of moisture and air, and ensure that the product remains fresh. To prevent oxidation of the cooking medium and development of rancidity, chips are generally packed in presence of nitrogen. Different types of packaging machines i.e. with and without nitrogen flushing are available in market (Figure 31).

Dehydrated products can be packed in polyethylene bags, but it should be ensured that the packaging film prevents the entry of air and moisture. Tins and cans are generally used for packing canned potatoes but can be used for dehydrated products as well.

Figure 31: Small scale packaging machine and packed potato chips

Popular Potato Products

10.1 Potato chips

Potato chips originally known as "Saratoga Chips" were first prepared by housewives in the Unites States of America during the middle of the nineteenth century. The production and popularity of potato chips has increased tremendously with the large scale manufacture of chips which began during the Second World War. The name "chips" has been used in America and "crisps" has been more popular in Europe. Potato chips have been considerably popularized by the potato chip manufacturing companies. With increasing popularity among all the sections of the society potato chips comprises 85% of the Rs. 2500 crore salty snack bussiness in India. The sector is still increasing with the production of potato chips from 0.38 million tonnes in 2006-2007 to 0.59 million tonnes in 2010-2011 and is expected to increase further to 3.55 million tonnes by the year 2050.

The quality of chips is determined by the golden colour and crispiness. Light golden yellow colour of chips is preferred while brown or black chips are unacceptable by the consumers. For producing good quality chips, potatoes should meet certain quality requirements. They should be round to round-oval in shape and size preferred is 40-60 mm diameter. Moreover to avoid losses during peeling and to maintain the shape of the chips, potatoes with shallow eyes are preferred for processing. Besides, the potatoes should possess a dry matter content of more than 20% and a reducing sugar level of less than 150 mg per 100g of tuber fresh weight. Potato varieties viz. Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chipsona-3, Kufri Chipsona-4, Kufri Himsona, Kufri Jyoti, Kufri Lauvkar and Kufri Chandramukhi are presently being used for preparation of chips.

Technology for making Potato chips

Complete process for chips preparation is shown in Figure 32.

Peeling: Potatoes are peeled with hand-held peeling knives or by hand/electrically operated potato peelers and washed thoroughly.

Peeling of potatoes with peeling knives is a time consuming and labour-intensive job and results in uneven peeling of potatoes. The hand or electrically operated peelers are available in different sizes which can peel about 15 to 60 kg potatoes at a time within 1-10 min depending upon the quantity, tuber shape, peel thickness and firmness of the tuber. Batch type abrasive peelers are recommended for peeling the potatoes in small scale processing units.

Trimming: Peeled and washed potatoes are trimmed manually and residual skin, eyes and green portions are removed.

Slicing/ shredding: Peeled potatoes are sliced and the slice thickness should be maintained between 1.5-2mm. Slices should have uniform thickness and smooth surface. Slices are washed to remove surface starch. Batch type slicers are available in the market.

Blanching: Washed slices are blanched to improve the colour especially when sugar level in potatoes is high and also to deactivate the enzymes. Blanching is done by dipping the slices in hot water (60-80°C) for 2-3 minutes.

Surface drying: After blanching slices are partially dried to remove excess moisture. A spin dryer can be used for this purpose.

Frying: Slices are fried at 180-190°C using a batch type fryer till the bubbling ceases. Kadhai can also be used to fry the slices. Normally electrically heated fryers are used in which temperature is indicated as well as controlled. Temperature control is needed for maintaining uniform quality of chips. Fried chips should be dried with the help of tissue towel to remove extra oil.

Packaging: The hot chips are uniformly salted or spiced and then are packed in polythene bags, preferably in presence of nitrogen to improve the shelf life of developed product.

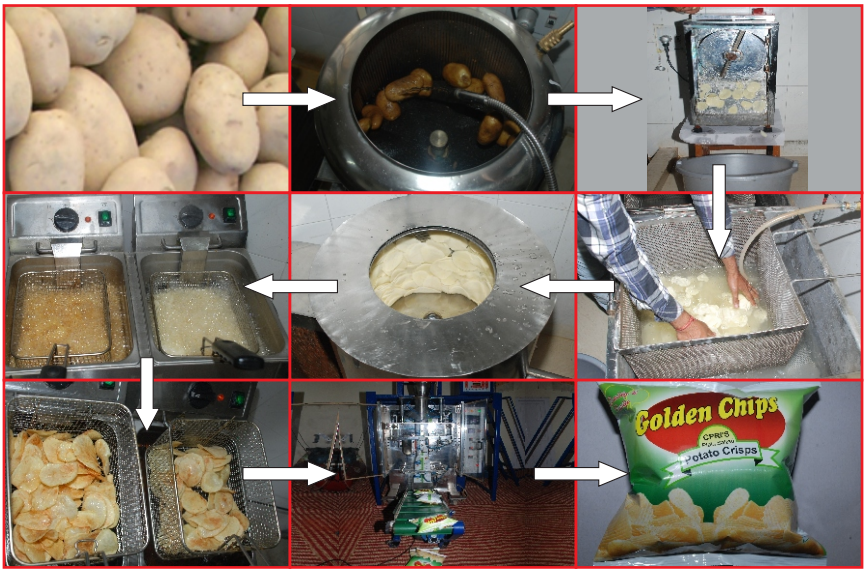


Figure 32: Potato chips processing machinery and prepared chips

PREPARATION OF POTATO CHIPS

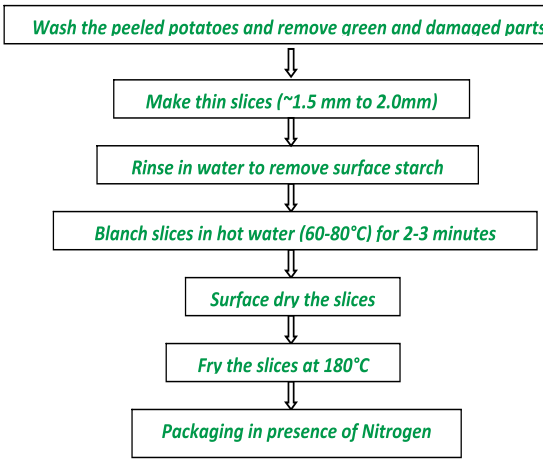


Figure 33: Potato chips

10.2 French fries

French fries are very popular in the developed countries including U.S.A. In India McCain is the largest French fry company. Approximately 0.6% of potato production was used for preparation of French fries in 2006-2007. Although India has huge French fry manufacturing capacities, but at present its actual processing is quite low. The limited number of outlets serving the product is one of the major reasons of its low utility and high price. However, the demand for French fries is increasing gradually. Generally, frozen French fries (par-fries) are prepared and sold.

Figure 34: French fries

In India the quantity of French fries consumed is much less compared to potato chips. However, the demand for French fries is increasing gradually. The quality of French fries is determined by the golden colour and crisp external surface and soft interior. Light or light golden yellow colour is preferred while brown or black colour is considered undesirable. Potatoes used for preparation of French fries are generally large and oblong. Moreover to avoid losses during peeling and to maintain the shape of the French fry sticks, potatoes with shallow eyes are preferred for processing. Besides, the potatoes should possess a dry matter content of more than 20% and a reducing sugar level of less than 150 mg per 100g of tuber fresh weight. Potato variety Kufri Frysona developed by CPRI is mainly used for French fry preparation due to its morphological and biochemical quality. Along with Kufri Frysona varieties such as Kufri Chipsona-1, Kufri Chipsona-2, Kufri Chipsona-3 and Kufri Chipsona-4 are also being used for preparation of French fries.

Technology for making French fries

French fries can be prepared on small scale following the simple procedure given below and the steps involve peeling, trimming, cutting into sticks, blanching, par-frying, freezing and finish frying. The procedure for making French fries is described below:

Peeling: Processing grade potatoes with high dry matter content and low reducing sugars measuring 7 cm or more in length are selected, washed thoroughly with clean water and then peeled using a peeler. Batch type abrasive peelers are recommended for peeling the potatoes in small scale processing units.

Trimming: Peeled and washed potatoes are trimmed manually and residual skin, eyes and green portions are removed.

Cutting: Peeled potatoes are cut into sticks of 10 x 10 mm (width × height) with the help of a French fry cutter. Sticks should have uniform thickness and smooth surface. Sticks are washed to remove surface starch.

Blanching: Washed sticks may be blanched to improve the fry colour especially when sugar level in potatoes is high. Blanching is done by dipping sticks in hot water (60-80°C) for 5 minutes. After blanching, sticks are partially dried to remove excess moisture. A spin dryer can be used for this purpose.

Par-Frying: French fry sticks are fried at 180-190°C for about 2 minutes using a batch type fryer. Normally electrically heated fryers are used in which temperature is indicated.

Freezing: The fries are dried with paper towel for removing extra oil, pre-cooled at room temperature, sealed and frozen in deep freezer (-20°C). The fries are stored till the final frying.

Frying: The final frying is done just before serving. French fry sticks are fried at 180-190°C till bubbling ceases (Figure 35). After frying the salt and spices may be added as per the taste and served.

PREPARATION OF FRENCH FRIES

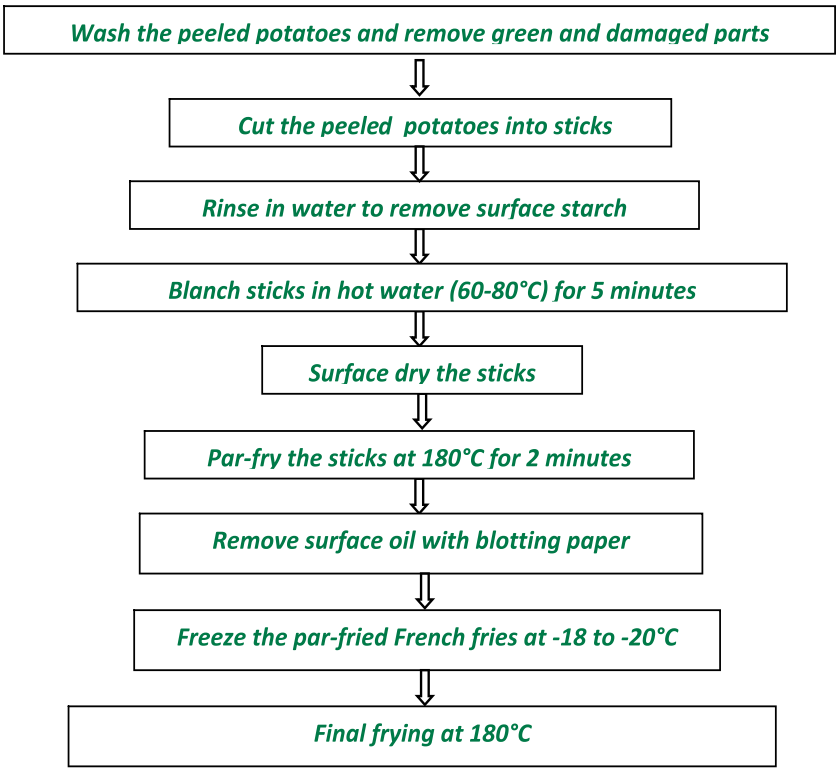


Figure 35: Frying process of French fries

Besides chips and French fries, several products of potatoes in combination of other food ingredients are being manufactured and sold in the market in ready to eat forms. Some of these include Smiley's, Wedges, Nuggets, Bites, Tikkis, etc., Processed potato, products like potato chips are no doubt popular but the cost of production of potato chips is very high because of the sophisticated technology used and high cost of frying medium and electricity. Therefore, these processed products are not within the reach of common man. In order to make the processed potato products

available to a large section of the population at an affordable price, simpler methods of potato processing are needed.

10.3 *Lachcha*/ Shreds

Potato shreds are prepared fresh as well as dehydrated at large scale. These shreds are being used alone or in combination with other snacks. For preparation of potato shreds tubers of any size and shape can be used. Even under sized, oversized potatoes as well as waste potato flesh during production of chips and French fries can be used for the production of shreds. Like chips and French fries, potatoes used for preparation of shreds should contain 20% or more dry matter and low reducing sugars i.e less than 150 mg/100g FW.

Technology for making shreds

Peeling: Potatoes are peeled with hand-held peeling knives or by hand/electrically operated potato peelers and washed thoroughly. Peeling of potatoes with peeling knives is a time consuming and labour-intensive job and results in uneven peeling of potatoes. The hand or electrically operated peelers are available in different sizes which can peel about 15 to 60 kg potatoes at a time within 1-10 min depending upon the quantity, tuber shape, peel thickness and firmness of the tuber. Batch type abrasive peelers are recommended for peeling the potatoes in small scale processing units.

Trimming: Peeled and washed potatoes are trimmed manually and residual skin, eyes and green portions are removed.

Shredding: Peeled potatoes are passed through the shredder to get thin and short shreds. Shreds are washed to remove surface starch.

Blanching: Washed shreds are blanched to improve the colour especially when sugar level in potatoes is high and also to deactivate the enzymes. Blanching is done by dipping the shreds in hot water (60-80°C) for 1-2 minutes.

Surface drying: After blanching shreds are partially dried to remove excess moisture. A spin dryer can be used for this purpose.

Frying: Shreds are fried at 180-190°C using a batch type fryer till the bubbling ceases. Kadhai can also be used to fry the shreds. Normally

electrically heated fryers are used in which temperature is indicated as well as controlled. Temperature control is needed for maintaining uniform quality of shreds. Fried shreds should be dried with the help of tissue towel to remove extra oil.

Packaging: The hot shreds are uniformly salted or spiced and then are packed in polythene bags, preferably in presence of nitrogen to improve the shelf life of developed product (Figure 36).

PREPARATION OF POTATO SHREDS

Wash the peeled potatoes and remove green and damaged parts

↓

Make shreds

↓

Rinse in water to remove surface starch

↓

Blanch shreds in hot water (60-80°C) for 1-2 minutes

↓

Surface dry the shreds

↓

Fry the shreds at 180°C

↓

Packaging in presence of Nitrogen

Figure 36: Potato lachcha /shreds

10.4 Potato flakes, flour and starch

Potato flakes can be prepared by drum drying of potato slurry that can be reconstituted at home very easily. Such reconstituted flakes can be used for stuffing purpose as it will eliminate need of boiling of tubers. Since the number of working ladies are increasing day by day therefore, this types of quick preparation has a huge market. Potato flakes can also be used in extruded product as well as fabricated chips development. Apart from potato flakes, potato flour and potato starch are the other products made from potatoes. More than 1% of the potato production is consumed by potato flakes and flour industry in India. In 2007-2008, the total quantity of dehydrated products manufactured in India was 31,000 tonnes.

Figure 37: Flour, starch and flakes developed from potatoes

Technology for making potato flakes

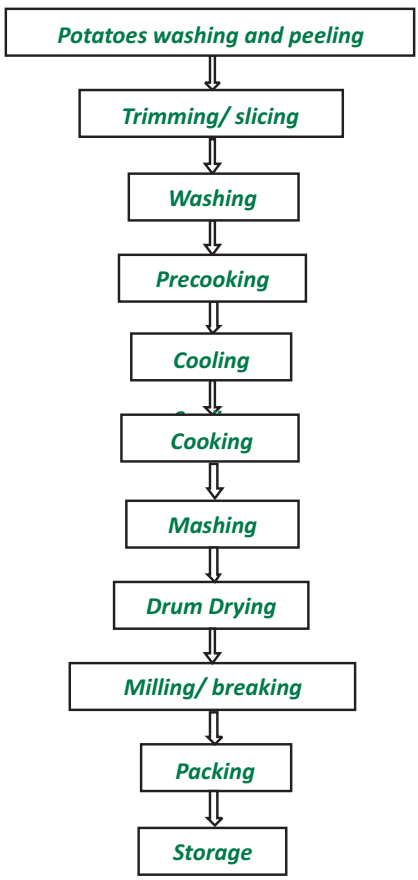
Peeling and trimming: Washed potatoes are peeled using steam peelers. The potatoes are heated in steam under pressure. The pressure is released quickly, the potatoes are cooled and the skin is removed using dry peelers. Peeled potatoes are washed and trimmed. Trimming is done to remove remaining skin and blemishes.

Slicing and cooking: Peeled potatoes are cut into slices, about 1-2 mm thick. The slices are washed to remove the liberated starch. The slices are then cooked in two stages, at first they are heated at 70°C for 20 minutes and cooled for 15 minutes in water at 12°C. They are then cooked at 100°C for 30 minutes. The initial heating and cooling helps to make the tissue firm resulting in the proper texture of the final product.

Ricing, drying and breaking: The cooked slices are mashed and passed through a perforated plate. The mash so obtained is dried on a roller drier. The drier is a hollow roller which is heated by steam. A layer of the mash is applied with the help of feed rolls. The moisture in the mash evaporates due to the heat. The dry layer is removed as a sheet and broken into flakes.

Packaging: The flakes have a moisture content of about 6-7%. To prevent oxidation of the product, the flakes are packed in nitrogen, generally in laminated packaging material. The packing should also exclude light. (Figure 37)

PREPARATION OF POTATO FLAKES



Potato flour: Potato flour can be used as a thickener-flavoring agent in soups, gravies, sauces and baby foods and is incorporated in the baking of bread to retain freshness. It also imparts a distinctive, pleasing flavour and improves toasting qualities besides its use for preparing several homemade finished products. Potato flour can be used in combination with other cereal and pulses flour for preparation of number of products like *biscuits, cake, bhujia and prantha* etc., Potato flour can be prepared from both table and processing potato cultivars of any shape and size. One quintal of potatoes will give approximately 20 kg of flour.

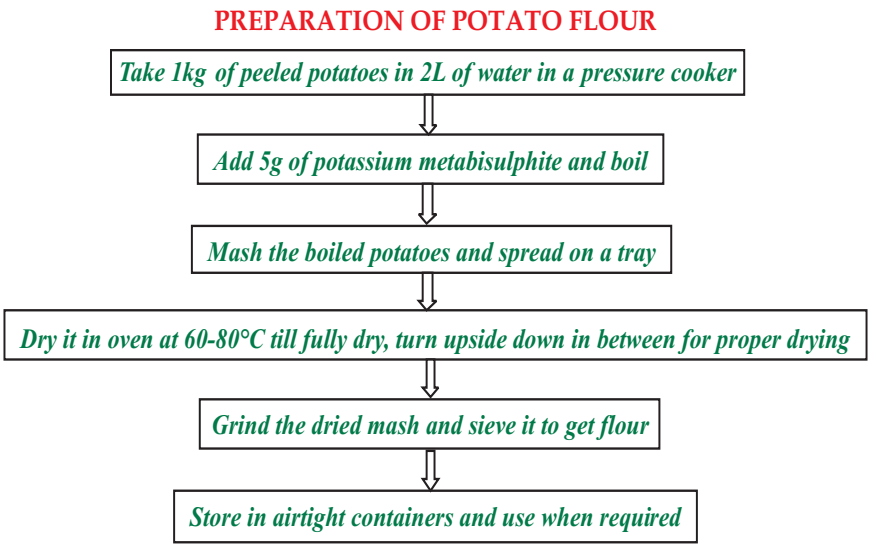
Technology for making potato flour

Cooking: Boil 1 kg of peeled potatoes in 2L of water containing 5 g potassium metabisulphite. After mashing the cooked potatoes, spread them on a tray in thin layer. The volume and quantity can be scaled up depending on the capacity of the processor.

Drying: Keep the tray in hot air oven at 60-80°C for drying. Turn upside down in between for complete drying of mash.

Grinding: After complete drying, grind the mash in domestic electrical mixer grinder to get powder and sieve it.

Storage: Store the sieved flour in airtight container until required (Figure 37).



Potato starch: Potato starch is being used in several industries for preparation of soups, gravy, puddings etc. Starch is being used in cakes, breads, biscuits and cookies as softening agent. Potato starch has high swelling power and high viscosity and due to these properties it is considered superior than the cereal starch and has wide application in paper, textile, food and pharmaceutical industries. Potato starch has been successfully used to make instant puddings and in this form it is preferred over cereal starches. It is also used in producing adhesives and dextrins, as a fermentation raw material, binder for tablets and binder and extender for sausages. Although, sub-standard, too small, too large, misshapen, damaged, cull and surplus potatoes can be used in starch manufacturing, but for high starch recovery, potatoes with high dry matter content are preferred. Both processing as well as non-processing potatoes can be used for starch extraction. One quintal of potatoes will give approximately 10 kg of starch.

Technology for making potato starch

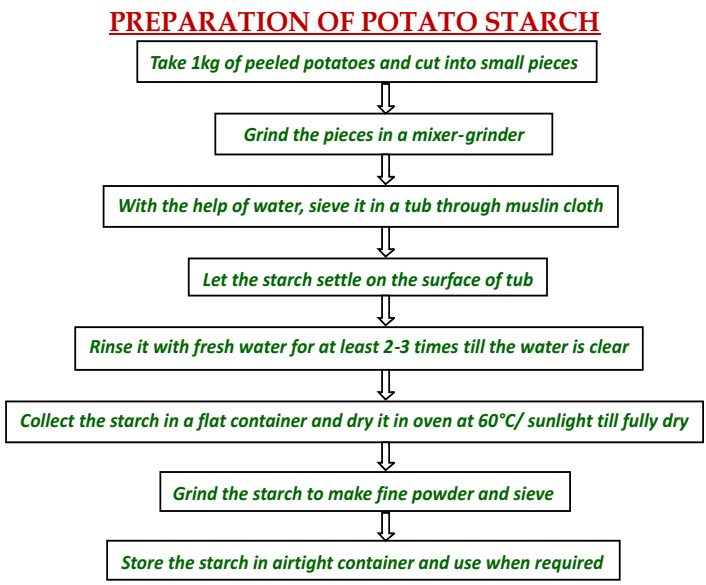
Cutting and grinding: Cut 1 kg of peeled potatoes to small pieces and add 1L of water containing 2.5g of potassium metabisulphite. Grind these pieces in domestic electrical mixer grinder to get slurry. The volume and quantity can be scaled up depending on the capacity of the processor.

Sieving: Sieve the starch through muslin cloth in a tub with the help of water. Allow the starch to settle on the bottom of tub. Discard water and rinse the starch with fresh water, until water becomes clear.

Drying: Dry the settled starch in hot air oven at 60°C or in sunlight until complete drying occurs.

Grinding: After complete drying, grind the starch in mixer grinder to get powder and sieve this powder (Figure 37).

Storage: Store the starch powder in airtight container until required.



10.5 Canned potatoes

For canning immature and small potatoes are preferred. However if large potatoes are used, they are cut into small pieces.

Washing and peeling: Potatoes are washed carefully to remove adhering soil and to avoid injury, especially if immature potatoes are being used. If necessary they are peeled using abrasive peelers.

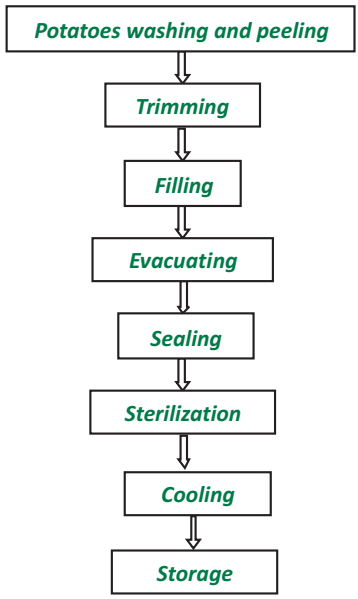
Blanching: Peeled potatoes are blanched in hot water for 4-5 minutes and cooled rapidly.

Filling: About 500 g of peeled potatoes are filled in a A21/2 size can. The cans are filled with 2% brine, leaving a head space of about 0.8 cm. Some calcium chloride is added to avoid the disintegration of potatoes during further processing.

Exhausting: The cans are exhausted by heating till the temperature in the centre of the can reaches about 80°C. This results in the removal of air from the liquid.

Sealing and sterilization: The cans are sealed and sterilized at 10 pounds per square inch pressure(psi) for 45 minutes and are cooled immediately. These cans can be stored at room temperature.

PREPARATION OF CANNED POTATOES



10.6 Dehydrated potato products- Chips and *lachcha*

Preservation of foods by drying is perhaps the oldest method known to man. Drying results in the lowering of moisture content, leading to lesser chances of microbial growth. As a result, the product has a longer shelf life. The reduction in moisture content is accompanied by a reduced bulk which facilitates storage, transportation and packaging. Potato slices can be dehydrated in the sun, stored and, fried and consumed when required. Dehydrated potato chips are the most common processed potato product in the rural and semi-urban areas in the country (Figure 38). Dehydration of potatoes offers several advantages: It does not require much investment and is labour intensive, therefore, can be taken up at the level of individual families. Dehydrated chips have longer shelf life at room temperature and can be stored easily. Solar dehydration of potatoes is very popular in several states like Maharashtra, Gujarat, U.P. and M.P. and, remains a viable alternative to expensive and sophisticated potato processing technology. Dehydrated potato chips are quite popular because they are much cheaper than potato chips produced by the organized sector.

Figure 38: Dehydrated chips

Dehydrated potato products are such food products, which are inexpensive, require no costly machinery, easy to prepare, have a longer shelf life and contain approximately half the fat content of the fresh fried chips thereby particularly suitable for the calorie-conscious people. In some parts of the country, small scale processors make dehydrated potato products at cottage industry level (Figure 39). Besides, being an inexpensive low calorie alternative to conventional fresh potato chips, dehydrated potato chips can be a source of income generation for unemployed youths of India.

Figure 39: Dehydrated shreds

Technology for making dehydrated potato chips/shreds

Peeling: Potatoes should be peeled using a peeler and washed thoroughly with clean water. Batch type abrasive peelers are recommended for peeling the potatoes in small scale processing units.

Trimming: Peeled and washed potatoes are trimmed manually and residual skin, eyes and green portions are removed.

Slicing/shredding: Peeled potatoes are sliced and the slice thickness should be maintained between 1.5-2mm in case of potato chips. Slices should have uniform thickness and smooth surface. Slicing can be done using manually operated or electrically operated slicers. Batch type slicers are also available in the market. For preparation of shreds, peeled potatoes are passed through the shredder to get thin and short shreds. Slices/ shreds are washed to remove surface starch.

Blanching: To inactivate enzymes and to remove excess sugar from the surface of the slices/shreds, blanching is done. Blanching is done by dipping the slices in hot water (60-80°C) for 2-3 minutes and shreds for 1-2 minutes. The blanched slices/shreds are washed in cold water, drained off and spread for drying.

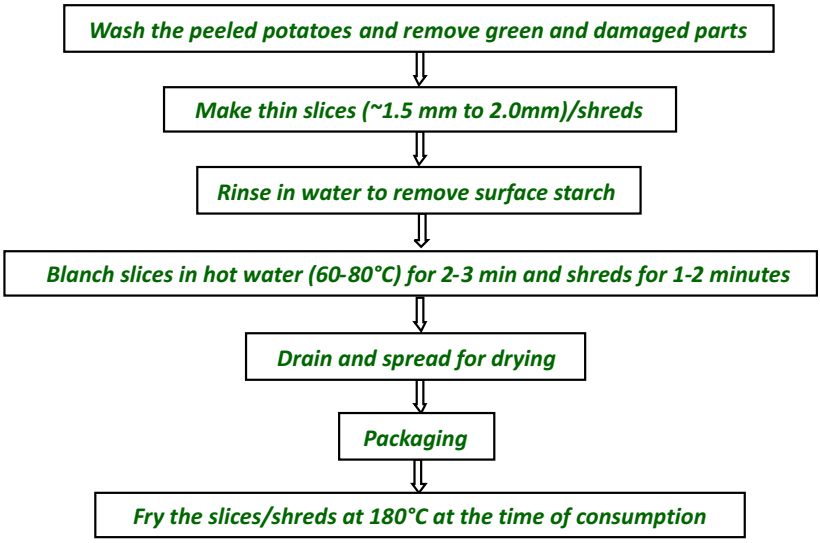
Drying of slices/ shreds: Shreds can be dried in sun. Dehydration of slices is affected by two important factors viz. slice thickness and surface. Black polythene is a better surface for dehydration than clear polythene. Drying can be done by two methods viz. solar dehydration and electrically heated driers. From 100kg of potatoes (containing 21% dry matter) approximately 17kg of dehydrated chips can be prepared.

Packaging: Dried slices/shreds should be properly packed in polythene bags. The dried product can be stored for several months after proper packaging.

Frying: Dehydrated slices/shreds are fried at 180-190°C using a batch type fryer. Shreds are fried in oil before consumption.

Figure 40: Dehydrated Potato Chips and Dehydrated Potato Lachcha

PREPARATION OF DEHYDRATED POTATO CHIPS/SHREDS



The technology used to prepare potato products are quite simple and can be adopted by Small Scale Food Industry, Self help groups, Mahila Mandals and Farmers Cooperatives. By adopting these technologies women can equally help their family to earn livelihood. Potato chips and *lachcha* making at small scale may provide additional remuneration of approximately 1000-1500 per day to the entrepreneurs. Processing of potatoes into products is imperative to maximize the utilization, to solve the problem of expensive refrigerated storage, to avoid market gluts and to save the precious food from spoilage. The feasibility to prepare potato products at small scale level requires less capital investment. There is an urgent need to encourage village level value addition of potato which can be easily adopted by the rural people and will generate addition income to improve their standard of living.

Possibility of new Potato Product Development

Potato is the most widely consumed tuber crops and well known as an essential part of daily diet. After the two major cereal crops i.e. rice and wheat, potato is in the third place which has the potential to provide bulk to the diet and to feed the masses as a source of food and nutrition. As far the production is concerned, after China, India is the second largest producer of potatoes in the world. In the year 2014-15, the total potato production in India was 44.89 million tonnes. Potatoes can be processed in various forms like chips, fries, dried products (chips, *lachcha*, papad, flakes etc.) by the organized and unorganized sector. Out of total produce of potatoes, 7.6 percent goes into processing, where 6.65% is used for chips making and 0.16 percent is converted into frozen product.

11.1 Need for new product development

The present processing percentage in potatoes is 7.6 which is expected to reach 20.57% by the year 2050 as per the VISION-2050 of ICAR-CPRI. Therefore, to bridge this gap (from 7.61 to 20.57%), innovative and indigenous processing technologies are required to satisfy the popular taste as well as present and future need of the consumers. This shows, with the existing product some new products need to be developed and their process standardized so that growers and manufacturers can get wider market and utilize their produce in much profitable manner.

In the year 2015, the population of India has reached ~ 127 Crore. Though, it is an issue of major demographic concern, on the flip side it provides a potential market for processed foods. The major proportion of population is consisting of teenagers who are fond of processed products. Therefore, India is a potential market for investors also. There is need to develop tasty, nutritious and low cost foods which can be within reach of common people and college going masses. In this direction, potato can be a good option which is easily available in bulk at reasonable price as a raw material and from which processed product can be formulated. Therefore, possibilities of new product development from potato need to be explored on an urgent basis and is being discussed here in detail.

11.2 Mineral fortification

Minerals are required for proper functioning of the human body. Under vacuum, mineral can be fortified in potato products through osmosis (Figure 41). This process is known as Vacuum Impregnation. As mineral are heat stable, therefore, they are expected to be retained after frying (thermal) and processing. In potatoes, work on ascorbic acid, zinc and calcium enrichment through vacuum impregnation has been reported earlier also.

Figure 41: Mineral fortified potato chips through vacuum impregnation

11.3 Folic acid enrichment

Potato contains good amount of folic acid i.e. 15-37 µg/100g which is equivalent to what is present in Wheat. The Recommended Daily Intake (RDI) of folic acid is 400 µg. Therefore, there is need and scope to enhance folic acid content in potato products. Keeping the importance of folic acid in view, presently in 60 countries including U.S.A., folic acid fortification is mandatory in flour.

11.4 Functional product development

Functional products are the products which can provide some additional health benefits apart from the basic nutrition. Potato flesh in its natural form is not a good source of antioxidants. Therefore, by osmotic process, antioxidants can also be impregnated into the potato flesh. Some functional components like anthocyanins from black carrot (Figure 42) and betanins from beet roots (Figure 43) has been successfully impregnated in potato chips and flesh, respectively.

Figure 42: Anthocyanins infused in microwaved potato chips

Figure 43: Betanins impregnation in potato flesh

11.5 Probiotics products

Like minerals and antioxidants, probiotics (live microorganism) can also be impregnated in potato flesh. Lactic acid bacteria (Genus: *Bifido* and *Lactobacillus*) are well known probiotics cultures. In market, in probiotic category, mainly dairy products are available like yoghurt etc., But people suffering from high cholesterol and lactose intolerance cannot frequently consume the dairy products. For them fruits and vegetable products enriched with probiotics is the better choice than the dairy products. Major limitations associated with the probiotic foods are the heat sensitivity, culture contamination, level of impregnation etc. therefore, while developing the products these things should be kept in consideration.

11.6 Extruded products

Extruded products like Kurkure, Bingo-Mad Angles etc. are very famous in Indian and global market. Variation in shape and size of

product can be achieved by extrusion technology (Figure 44). In this, ingredient mixture is exposed to high pressure and when this batter comes to the contact in atmospheric pressure (low pressure), volume expands and more puffy and light product is formed. Extrusion is a HTST (High Temperature Short Time) process. Therefore, product obtained after the extrusion process is equivalent to the pasteurized product.

Figure 44: Extruded product made by potato and cassava

11.7 Salad dressings

Salad dressing is Oil-in-Water emulsion which can be utilized to make food product more tasty and attractive. In its natural form emulsions are unstable especially when it's fat content is reduced up to 60-65%. Its stability can be enhanced by addition of stabilizer as it will not allow free movement of fat droplets. Potato starch can be an effective stabilizer and thickener which have the capability to produce the hindrance for the movement of fat droplets and not allowed them to move out of the food matrix. As per the work conducted in West Pomeranian University of Technology in Szczecin, Poland, potato starch at 5% level can be used to stabilize the salad dressing prepared by egg yolk and sodium caseinate. However, work on potato based salad dressing is in its infancy stage

though the possibilities for functional product development in the form of salad dressings are very high.

11.8 Resistant starch

Resistant starch is also a functional component which is well known for its health benefits. It resists the normal digestion procedure in small intestine and goes into large intestine directly. It can be formulated by treating the starch at high temperature, enzymes and chemical reactions. Fortified products formulated by addition of Resistant starch contain high fibre content. Some commercially available Resistant starch are Hi maize, Novelose-240, 260, 200, CrystaLean and Fibersym etc.

11.9 Bakery products

Bakery Industry is the largest food Industry in Food Processing Industry Sector. Gluten is an important ingredient in bakery product development. Biscuits and Breads make 82% of the total processed bakery products. Potato flour when added in biscuits, cakes and baby foods, the digestibility and availability of protein, starch and minerals gets enhanced. Potato flour is cheap and nutritious source of carbohydrates and doesn't have gluten. It has the potential to replace some amount of gluten in bakery products for which gluten is not very important like Biscuits, Cookies and Cake etc., Potato starch is a well-known thickener, gluing and bulking agent. Due to bland taste, potato flour can be used in most diversified manner. It can be utilized in making stiff porridge and ice cream cone for which till date maize and wheat are the most common raw materials.

11.10 Peel containing product

Potato peel is a potential source of nutraceuticals, minerals and antioxidants. It's per 100 g contains 3 mg iron, 10 mg calcium and 400 mg potassium. Among macro nutrients, it contains 2.57g proteins and 2.5 g fibre. Its nutritional advantages can be extracted when utilized as food ingredients in any food formulation. Potatoes having thin peel can be utilized in soup preparation. Similar type of product is famous in the hilly region of Uttarakhand. Such type of product can be processed through retort processing also. If cereal or

pulse flours would be selected to provide thickness to the soup in a manner that it can also balance the amino acid profile of the soup, then such product will be very nutritious and can be prepared at home scale as well as at industrial level also.

11.11 Minimally processed foods

The segment of minimally processed foods is practically unexplored in case of potato. However, physical and chemical stability of each functional compounds and probiotics will be higher in minimally processed foods compared to fried products. Various non-thermal techniques are there which can make product digestible without increasing the temperature much like High Pressure Processing (HPP). But these techniques need lots of capital investment. Enhancement in resistant starch content through high pressure processing has been done in various laboratories.

11.12 Low fat potato products

Microwave is generally used for cooking purpose. But microwaving can be used for drying of potato chips and to make them palatable without addition of oils with baked flavour (Figure 45). It is good for persons suffering from obesity. Not only by the microwaving but through hydrocolloid coating also fat content can be reduced. Lots of research work has been done in Islamic Azad University, Iran to reduce the fat content of chips and fries by using hydrocolloid coatings.

Figure 45: Microwaved Potato chips

11.13 Modified starch production

Potatoes that can be not be utilized for making chips or French fries can be utilized in modified starch preparation. As potato chiefly

consists of starch, therefore, it is relatively easy to isolate starch from its other components. Till date maize is mainly used for the modified starch development from which refining and isolation is very tedious job as all components/layers are fused intensively.

11.14 Processing of traditional homemade potato products

There are varieties of traditional products that can be made at home scale level like stuffed *aaluparatha, samosa,* vegetable curries etc. D.R.D.O.-Defence Food Research Laboratory, Mysore has developed a technology for stuffed aaluparatha that can be shelf stable up to 12 month in retort pouch without use of any chemical preservatives. Like-wise for other home-made preparations, shelf-life extension can be achieved. Such products have a great demand as a food for defence people.

Conclusion

The area under potato and the production have been increasing consistently over the years in India. Periodical gluts have not discouraged the farmers of this country from growing the potato crop. Going by present indication potato production will continue to increase and we should be prepared to utilize the surplus potatoes and avoid wastage of this wholesome food. Processing of potatoes and value addition will be necessary for better utilization.

Potatoes can be grown in areas where the temperatures are favourable for higher dry matter production. As we have identified areas suitable for producing good quality seed potatoes, we should clearly demarcate areas suitable for producing potatoes for processing.

The availability of fresh potatoes is high only during the harvesting season and during most part of the year availability of fresh potatoes for processing is low. Therefore, storage of potatoes becomes important in order to ensure the availability of potatoes in sufficient quantity for processing, throughout the year. To maintain round the year supply, potatoes are being stored at 10-12°C with CIPC treatment. However, indigenous potato storage methods can prove to be useful for short-term storage (3-4 months) of processing potatoes.

In this bulletin, procedures have been given for the preparation of various potato products. Besides, potatoes can be processed into a variety of other products such as fortified potato products.

Research work is going on for product development in various laboratories of India and abroad that can be commercialized in future. Their commercialization will not only give varieties of foods to the consumers but by this we will also be able to utilize the bulk of total produce of potatoes through value addition. Processing can open the new dimension of earnings to small and marginal farmers. Only there is need of low cost technology like Vacuum Impregnation that can be easily adopted by the industry to make

nutritious and functional food products. Minimally processed food sector is totally unexplored in case of potatoes. Probiotic products and product made by potato flours are good for lactose and gluten intolerant people. Consumer preference needs to be evaluated fully so that the acceptance can be predicted or estimated for new products. This will help in prioritization for standardization of those products which will have the good future and demand in the market.

Go East or West
Potatoes are the Best

Suggested Readings

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