POTATO

Post-harvest Operations

INPhO - Post-harvest Compendium

Food and Agriculture Organization
of the United Nations

POTATO: Post-harvest Operations

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Preface

The potato is a staple food belonging to the tuber and root family, which now enjoys increasing extension to the developing world. One of the top four crops in the world, it is prized as a fresh nutritious product or as the basis of a myriad of processed foods.

This chapter of the compendium will trace the potato from its origins in developed regions to practical techniques to incorporate it into the diet and economy of developing nations.

1. Introduction

The potato is a critical essential food in developing countries claiming fourth place after rice, wheat and corn. These countries produce approximately one-third of the worldwide production of potato. It is a fat-free food containing protein, vitamins and minerals.
Though commonly consumed fresh, the tuber is quite versatile and may be used frozen, fried or dehydrated (flakes) among other derived foods. Further, new applications are extending the potato for agroindustrial usage. In addition potatoes are used for seed and animal feed.
The post-harvest technology will assist in improving production and tuber use. The objectives to advance the crop involve greater productivity, lower production costs and better storage conditions.
Long term potential of potato use is based on derived products. Continued diversification of potatoes throughout the globe can boost the number of prepared foods.

1.1 Economic and social impact of the potato

Most the production of potatoes comes from Europe, Eastern Europe and the Russian Federation. Recently, developing countries have increased their participation. This situation has evolved rapidly indicating that a sustained trend will result in most of the world production of tubers coming from Asia, Africa and Latin America.
In fact, the high productivity level in developed countries in Europe, North America, Australia and others have left few possibilities to augment potato production by convention methods.
A majority of the world potato production is dedicated to the direct human consumption (50-60 percent). Around 25 percent are used to feed animals. Approximately 10 percent are dedicated for seed. The difference, in large part, is its use as raw material for industrial products. A smaller measure of tubers is counted as losses.
In Europe and North America, the potato varieties currently in consumption have barely altered for many years. For example, the variety of more consumption in United States (Russet Burbank) had appeared in 1872. In a similar way, new varieties have hardly been introduced in Europe. The efficient certified seed programs, easy access to pesticides, the sterilizing effect of the hard winters plus the expansion of the processing industry has all influenced the consolidation of tubers.
In the last 20 years, the developing countries have been more willing to accept the introduction of new varieties. Genetic improvement together with more efficient production programs and seed distribution offers positive base to improve productivity levels.
The integrated practices of pest control have demonstrated outstanding success in the Andes of South America and in North Africa. The sustained expansion of these techniques, often combined with cultural production practices (improved seed) and post-harvest (rustic storage) will result in larger quantities of produced and marketed potatoes.

1.2 World Trade

Over the years, potato supply and demand has followed divergent paths. The cultivated area and production in Europe has experienced reductions, with some exceptions like the Netherlands and Portugal. Most of the production of the developed countries (84 percent) is concentrated on Europe and the countries that were part of the Soviet Union. Mainly North America, Australia, New Zealand, Japan, South Africa and Israel produce the remaining crop. The potato crop productivity average in Africa, Asia and Latin America has increased 44 percent, 25 percent and 71 percent, respectively, within a 30 year-old period. Potato production and yield vary considerably among countries in Latin America. Generally, there has been a slight reduction of the cultivation area offset by a productivity increase. The tendency to reduce the growing area in Latin America has led to concentration in more productive areas. High yields have been obtained comparable to those of Asia and Africa. Colombia and Mexico have the highest growth rates.

Mainly small and medium farmers in the developing countries cultivate potato. This situation is reflected in most of the region except Argentina where large farmers prevail. See Tables 1 and 2 for more detail.

Asia has exhibited the biggest rate of potato production growth in the world. Lower prices established as a consequence of the improvement in production systems and storage plus population growth and higher incomes have stimulated a bigger demand for potatoes.

The foremost rate of area crop growth has occurred in Africa, even if the production levels and productivity are lower than those of Asia and Latin America. In North Africa, demographic growth and the biggest incomes have contributed to make the potato crop more profitable. In the Sub-Saharan Africa, the rural demographic growth and the capacity to partially replace the seasonal shortage of the cereals, have contributed to the potato crop's diffusion. The main producers in the region are Egypt and South Africa.

Table 1. Potato Production Land Tenure by Countries

Country	**Type of Holding**	**Land Tenure**	
		Size (ha)	**Percent**
Peru	Miniature	1<	35
	Small	1 to 3	40
	Medium	3 to 20	20
	Associative and Large	>20	5
Colombia	Small	3<	55.5
	Medium	3 to 10	34
	Large	>10	10.5
Costa Rica	Small	0.5 to 5.0	70
	Medium	5 to 20	25
	Large	>20	5
Bolivia	Small	1<	80
	Medium	1 to 10	15
	Large	>10	5
Venezuela	Small	5<	38
	Medium	5 to 20	37
	Large	>20	25
Ecuador	Small	10<	90
	Medium	10 to 100	9
	Large	>100	1

Source: CIP. Programa Cooperativo de Investigación de Papa (PRACIPA), 1984.

Table 2. Land Tenure in Potato Production in Argentina (County of Buenos Aires). Years 1964-1965.

Farm size	**Harvested area (%)**
Small up to 5 ha	2.6
Medium 5 to 10 ha	16.2
Large >21 ha	81.2

Source: Alvaro Montalvo, 1984.

Table 3. Potato World Production by Regions and Selected Countries. Averages of 1961-1963 and 1991-1993.

	Average 1961-63			Average 1991-93			Production Annual Average Growth Rate (percent)[1]
	Production (000t)	Area (000 ha)	Yield (T/ha)	Production (000t)	Area (000 ha)	Yield (T/ha)	
World	265 114	22 155	12	275 355	18 133	15	0.1
Developed Countries	236 048	18 592	13	190 398	11 456	17	-0.7
Western Europe	84 981	4 597	18	49 671	1 634	30	-1.8
Belgium-Luxembourg	1 842	67	27	2 355	57	41	0.8
France	14 565	866	17	6 002	173	35	-2.9
Germany	35 677	1 679	21	11 247	338	33	-3.8
Italy	3 959	380	10	2 247	103	22	-1.9
Holland	3 842	132	29	7 415	177	42	2.2
Portugal	1 031	106	10	1 394	102	14	1
Spain	4 715	412	11	4 728	244	19	0
United Kingdom	7 064	318	22	7 045	176	40	0
East Europe	56 271	4 308	13	38 989	2 539	15	-1.2
Hungary	2 092	257	8	1 132	69	16	-2
Poland	42 629	2 856	15	29 565	1 750	17	-1.2
Rumania	2 721	312	9	2 728	234	12	0
Former USSR	75 274	8 687	9	72 893	6 392	11	-0.1
Bielorussian	9 273	960	10	9 862	727	14	0.2
Russian Federation	43 174	4 904	9	36 869	3 383	11	-0.5
Ukraine	17 640	2 066	9	18 592	1 588	12	0.2
Other	19 523	1 000	20	28 845	892	32	1.3
Australia	557	40	14	1 139	39	29	2.4
Canada	2 082	120	17	3 261	123	27	1.5
Japan	3 652	214	17	3 498	111	32	-0.1
South Africa	355	49	7	1 257	61	21	4.3
United States	12 543	560	22	19 227	540	36	1.4
Developing Countries	29 066	3 562	8	84 957	6 677	13	3.6
Asia	20 280	2 327	9	66 037	4 995	13	4
Bangladesh	347	57	6	1 333	127	10	4.6
China [2]/	12 908	1 434	9	34 435	2 960	12	3.3
India	2 844	384	7	15 771	1 014	16	5.9
Indonesia	62	10	6	679	47	14	8.3
Iran	317	30	11	2 847	149	19	7.6

	Average 1961-63			Average 1991-93			Production Annual Average Growth Rate (percent)[1]
Korea, PRD	1 000	93	11	1 842	150	12	2.1
Nepal	233	41	6	735	86	9	3.9
Pakistan	119	14	9	848	74	11	6.8
Syria	32	3	11	408	23	18	8.9
Turkey	1 498	141	11	4 617	195	24	3.8
Vietnam	45	3	15	278	29	10	6.3
Africa	1 826	238	8	6 693	700	10	4.4
Algeria	234	23	10	1 135	114	10	5.4
Egypt	389	24	16	1 702	82	21	5
Madagascar	83	12	7	276	39	7	4.1
Malawi	62	21	3	360	95	4	6
Morocco	197	21	9	957	60	16	5.4
Rwanda	79	21	4	364	40	9	5.2
Latin America & Caribbean	6 959	998	7	12 226	981	12	1.9
Argentina	1 570	171	9	2 015	111	18	0.8
Bolivia	531	110	5	687	120	6	0.9
Brazil	1 127	196	6	2 353	165	14	2.5
Chile	819	92	9	931	62	15	0.4
Colombia	665	64	41	2 456	161	15	4.5
Cuba	96	8	12	231	16	14	3
Ecuador	284	32	9	433	58	7	1.4
Mexico	366	47	8	1 211	73	17	4.1
Peru	1 224	232	5	1 314	165	8	0.2

Source: CIP-FAO, 1995 1. - 1961-63/1991-93 2. - Includes Taiwan

The potato is a substantial, perishable product of low intrinsic cost and high transport expense, which limits its export possibilities. In spite of these drawbacks, the exports of fresh potatoes have increased slightly.

The appearance of new markets and the development of potato processing industry have increased the profitability of the product. This has raised the appeal of participation in this market. Better infrastructures have contributed to facilitate commercial development.

Supply diversification is driven by the effective demand of new products. In the period 1991 to 1993, the potato international trade transactions exceeded 7.5 million tonnes.

Table 4 displays the imports and exports of some potato developing countries for the 1991 to 1993. The external potato trade of Latin America and the Caribbean countries for the 1961 to 1963 and 1991 to 1993 periods is shown in Table 5.

Some consider that the potato international trade, including to the countries in the European Union, could potentially reach 10 million annual tonnes or 4 percent of total world production.

Table 4. Potato External Trade of Selected Developing Countries, 1961-1993[a] (thousand of tonnes and percentages).

Regions and Countries	1991-1993		Annual Average Growth Rate	
			1961-1963/ 1991-1993	
	Imports	Exports	Imports	Exports
Asia [1]	673	903	3.8	6.2
China	-	71	-8.7	7.2
Turkey	6	279	-	29.5
Indonesia	1	107	1.6	1.8
Syria	7	104	-2.9	15.7
Africa [2]	277	316	-0.1	0.9
Egypt	20	201	0.6	2.7
Algeria	94	2	-1.8	-11.8
Morocco	30	97	-0.9	0.6
Latin America & Caribbean	297	74	1.2	3.2
Colombia	-	45	-	10.3
Brazil	8	-	0.9	3.8
Guatemala	1	6	-	3.2
Mexico	29	1	9.7	-
Developing Countries	1 250	1 293	1.9	3.8

a. Only referred to fresh and seed potato trade 1. Asia: Japan, Kazajstán, Uzbekistán, Kirgyiztan, Armenia, Israel, Georgia, Azerbaiyan, Tayikistán and Turkmenistan. 2.
Source: FAO, Faostat-pc, No Published Statistics, 1996.

The impetus in world potato trade at present may be characterized as more dynamism, better participation of developing countries, enhanced supply diversification and superior crop commercial profitability.

In the 30 year period from 1960 to 1990 developing countries have converted into net exporters from importers with a surplus of 43 402 tonnes in the period 1991-1993.

The world export growth is largely due to Latin America. Asia and Africa have diminished exports, while those of Europe, the United States and Canada remain stable.

In Latin America, although exports have grown more than imports, the region continues to be a buyer. The type of potato that is imported varies according to the given country. Purchasing potato for seed is more important for Venezuela, Cuba and Uruguay. Processed potato and potato for consumption is significant in Mexico and the Caribbean. The Netherlands is the most important supplier of processed potato.

In Europe, the demand for fresh potato consumed by humans and animals has minimized contrasting to the mounting demand for processed potato.

Table 5. Latin America and Caribbean: Potato External Trade, 1961-1963 and 1991-1993[a] (metric tonnes, 3 year average (000))

	1961-1963		1991-1993	
	Export	**Import**	**Export**	**Import**
South Cone	21	101	13	88
Brazil	1	6	-	27
Argentina	13	49	6	18
Chile	7	2	5	7
Uruguay	-	41	2	23
Paraguay		3		-
Andean Area	2	32	48	267
Colombia	2	-	45	1
Peru	-	15	-	27
Venezuela	-	15	1	88
Mexico	0	2	2	151
Central America and Caribbean	6	86	25	271
Cuba	-	38	-	35
Costa Rica	-	-	-	-
Guatemala	4	-	16	1
Nicaragua	-	1	-	10
Dominican Republic	-	2	-	0
Honduras	-	2	5	2
Panama	-	1	-	1
El Salvador	1	4	-	14
Jamaica	-	5	-	1
Other	1	33	4	207
Total	27	219	86	626

Source: FAO, Faostat-pc, Statistical Unpublished, 1996. [a] Only referred to fresh and seed potato trade.

The potato industry has experienced great growth in recent decades. In the Netherlands and the United States, industry absorbs between 55 and 60 percent of potato annual production. In 1959-1960 potato production volume dedicated to processing in United States was scarcely 4 percent compared to 32 percent registered during 1989-90. In 1960, only 6 000 tonnes of frozen French fries were processed in Holland, while in 1990 1.47 million tonnes were processed.

In developing countries, the industrial use of the tuber is still incipient, although this perception may be distorted by a lack of reliable statistical information.

Tables 6 and 7 list potato use production percentages for Ecuador and Peru. As more than 70 percent use is allocated to fresh consumption, processing remains small at 1 and 2 percent for the two countries.

Table 6. Potato Use in Ecuador in One Year

Use	**%**
Human consumption, fresh potato	72
Animal consumption, waste	7
Seed	20
Industrial	1

Source: IICA-Prociandino, 1990.

Table 7. Potato Use in Peru

Use	%
Seed	15.8
Self consumption	34.6
Sale	39.9
Processing	2
Animal Consumption	1
Exchange	1
Other	5.7

Source: IICA- PROCIANDINO, 1990

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Figure 1: ***Potato Sale at an Andean Fair***

Nevertheless, there exists a marked tendency to dedicate a bigger tuber volume for processing, with the aim of satisfying a mounting demand for fast food, snacks and prepared foods.
The structure of the demand in Latin America is changing, where the volume of processed products is growing. Although the available statistics don't permit clear appreciation of this fact several studies have explored the current and potential economic importance of the potato as an agroindustrial input. For example, in Colombia 12 percent of the potato production has industrial use, while between 16 and 19 percent of the potato production is dedicated to processed products for the urban market in Mexico. Table 8 outlines the potato production percentages in the United States and countries of Latin America.

Table 8. Use of Fresh Potato Production for Processing in Some Countries

Country	%
Peru[3]	2
EE. UU.[2]	>50
Guatemala[1]	3 to 4
Ecuador[4]	1
Mexico[1]	10
Venezuela[4]	10
Costa Rica[1]	10
Panama[1]	30
India[1]	0.03
Colombia[1]	12
Chile[3]	15

Sources: 1) Scott J. Gregory *et al*, 1997;2) Brandes Salazar,
Dazzy, *et al*, 1997;3 Obbink Maarten, 1996; 4) IICA - Prociandino, 1990.

The potato is still barely used as agroindustrial input in Latin America. Argentina has built a potato processing transnational plant representing an investment of 25 million dollars. Other countries, as Chile, Colombia, Ecuador and Peru will be receiving important national and foreign investments.
Table 9 shows the potato processed products consumption volumes in Peru (Metropolitan Lima).

Table 9. Consumption of Potato Processed Products in Metropolitan Lima (Peru)

ITEM	**MT**
Potato Starch	1 756
Dried potato	From .425 to 2 290
Potato puree	91
Chips	874
Chuño potato	77 (for 1980)
Peeled and cut potato	9 600

Source: Wong, David *et al*, 1987.

Recently, the potato has exhibited great potential and versatility as an export item. Flakes, starch, flours and frozen potato products now join traditional fresh potato consumption and seed for import/export.
Table 10 displays the exports of processed potato products of Peru.
The main importers of frozen fried potato in the Latin America region are Mexico, Brazil, Chile, Argentina and Venezuela. Frozen fried potato comes mainly from United States and Canada.
Table 11 summarizes the imports of frozen French fries for Latin America and the Caribbean.

Table 10. Exports of processed potato of Peru, 1995 to 1997 in kg

Year	Total Exports	Prepared or Preserved[1]	Cut into Pieces or Dry Slices	Flour, Starch & Potato Flakes	Frozen	Frozen Precooked
1995	100 703	3 257	34 010	31 353	0	32 084
1996	145 864	3 626	26 478	44 230	50 000	21 530
1997	54 443	0	14 389	54	0	40 000

Source: Wong, David *et al*, 1987. 1. Except in vinegar, acetic acid. * Include January . May (First week).** Own estimate based on involved companies interviewed.

Table 11. Latin America and Caribbean: Frozen French Fries Imports

Country	1991-1992				1994-1995			
	United States	The Netherlands	Canada	Total	United States	The Netherlands	Canada	Total
South Cone	504	999	1 336	2 838	18 761	10 674	21 845	51 280
Brazil	219	989	577	1 784	12 184	5 998	13 903	32 086
Chile	134	10	108	252	3 734	3 490	2 197	9 420
Uruguay	-	-	149	149	932	613	1 018	2 563
Argentina	150	-	502	653	1 912	573	4 727	7 211
Andean Area	27	-	1 323	1350	1 361	428	916	10 319
Ecuador	20	-	-	20	949	-	16	965
Colombia	7	-	16	23	192	42	497	730
Peru	-	-	83	83	221	-	1 611	1 832
Venezuela	-	-	1 224	1 224	-	-	6 792	6 792
Central American & Caribbean	6 122	1 496	4 920	12 538	14 377	1 846	15 551	31 774
Guatemala	429	-	-	429	3 950	-	-	3 950
Netherlands Antilles	359	-	1 320	1 679	1 546	-	2721	4 267
El Salvador	227	-	-	227	1 495	-	140	163
Jamaica	481	-	-	481	1 402	-	1 719	3 121
Honduras	316	-	-	316	1 213	-	350	1 562
Belize	787	-	-	787	996	-	19	1 015
Bahamas	2 322	-	436	2 758	803	-	578	1 381
Dominican Republic	74	-	116	190	796	55	10	861
Costa Rica	315	-	-	315	610	-	18	628
Other[2]	812	1 496	3 048	5 356	1 565	1 791	9 996	13 352
Mexico	14 649	-	541	15 190	33 385	-	688	34 073
Total	21 302	2 495	8 120	31 916	67 885	12 562	47 000	127 446

1. Based on fresh potato weight using a pound of frozen potato as equivalent to two pounds of fresh potato and converted to metric tonnes. 2. In the case of The Netherlands, exports went mainly to Curaçao, Aruba, Martinique, Guadeloupe, Haiti and Bahamas; in the case of Canada to Trinidad and Tobago, Jamaica, Barbados and Cuba.

1.3 Secondary and Derived Products

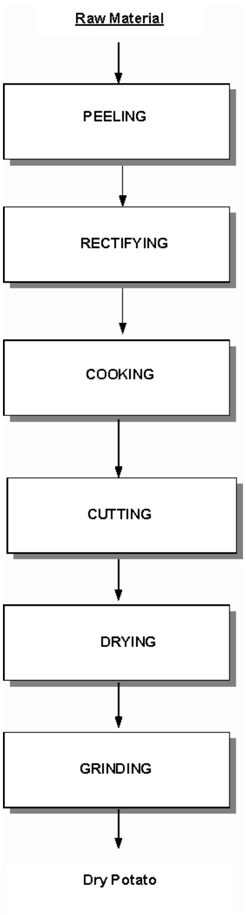
From season to season there are strong variations in potato prices and volumes. Processing allows the possibility to add value to fresh potato. This is particularly important in times of abundance, when the tuber price is lowest.
Processing allows part of the harvest to be retired from the market, thus introducing certain price stabilization. It also prolongs tuber shelf life (dry potato, flour), employs below standard varieties for direct consumption (bitter potatoes) and potatoes of little commercial value (very big, very small, unsightly).
The potato used for processing should have:

- High content of dry matter;
- Low content of reducing sugars;
- Low glycoalkaloids content;
- Appropriate content of phenolic compounds.

1.4.1 Traditional Products

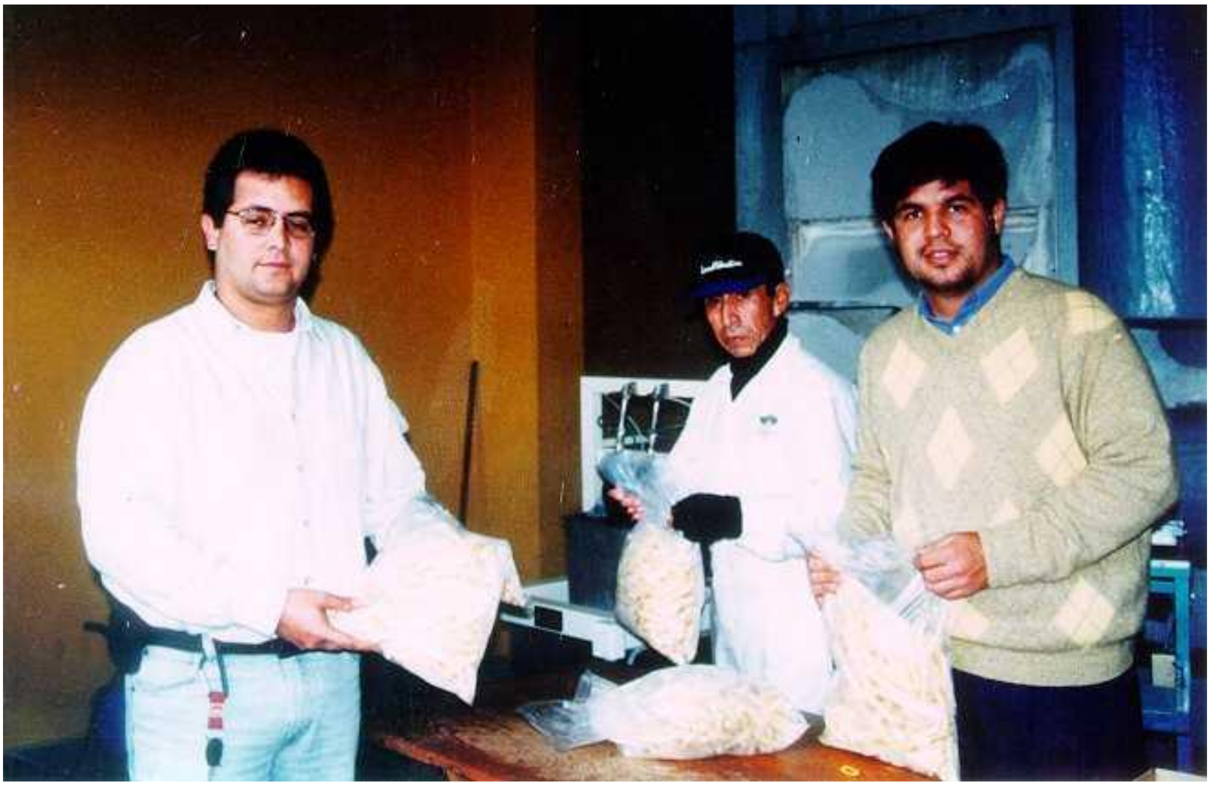
Dry Potato

The process for dry potato is shown in Diagram 1.



Description of the Process:
The potato crop comes from the field in jute sacks or polypropylene bags. It is weighed before entering the productive process. Visual selection is carried out to eliminate the potatoes that exhibit contusions, signs of microorganism attack or any other deterioration.
Tubers are washed in a machine that generates a shower of water, with rollers fitted with nylon bristles.
A peeling machine peels the potatoes by abrasion. The peeled potatoes go into baskets and are sunk in a tub of water.
The peeled potatoes undergo a pre-cooking stage in boiling water to avoid browning and improve final yield.
Then potatoes are passed to a rectifier, to eliminate "eyes", remains of shells and damaged parts.
Potatoes are cut in strips of 1x1 cm traverse section and variable longitude, using manual or vertical disk cutters.

Figure 2:Potato Peeled and Strips Cutting

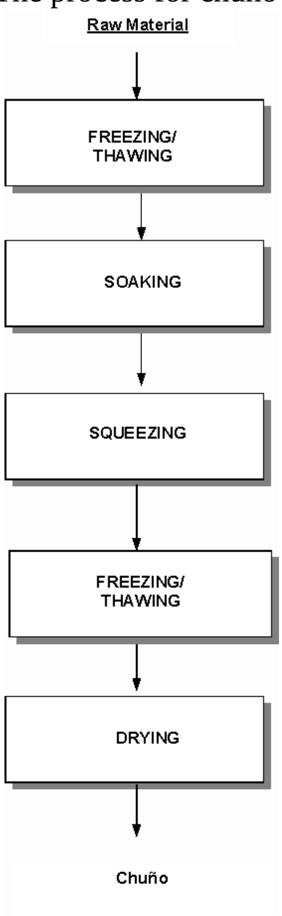


Cut potatoes are distributed evenly on trays or meshes to facilitate drying. The load is of 8-10 kg by m2.
Drying is traditionally completed in the environment, but it is recommended to use a hot air dryer at 65 ^{o}C for 8-10 hours or a solar dryer for 3-6 days, up to constant weight.
Once tubers are dry and cooled to ambient temperature, dry potato is ground in a hammer mill to 1 700 RPM with a mesh of 3/4 inch diameter. Also a disk or a ball mill can be used.
A screening step separates fine dust that originated in the mill. The yield is approximately 20 percent.
Dry potato is packed in high density polyethylene bags. Its capacity varies according to the destination market and quantity (150 g, 250 g, 500 g, 10 kg, 25 kg and 50 kg). It is recommended not to store dry potato at temperature and relative humidity higher than 26.6 ^{o}C and 75 percent HR.

Figure 3:Potato dehydrated by sun

Chuño

The process for chuño elaboration is shown here in the Diagram 2.



Description of the Process:

Bitter varieties are used, with a high glycoalkaloids content that cannot be consumed fresh.

The best months for Chuño elaboration are June and July, because of freezing intensity.

The potatoes are classified by size so the freezing is uniform and the final product homogeneous.

The beds dedicated to Chuño preparation is located in places with altitudes between 3 600 and 4 000 msnm, where cold is intense. They are prepared with Ichu (*Stipa ichu*) that extends on the floor in mesh form, to distribute the potatoes in one layer. Exposure time necessary for freezing varies from 2 to 4 nights, depending on how cold it is.

Potatoes are defrosted by sunshine in the morning. Water is thawed from cellular structure (constitution). The potatoes lose between 25 and 30 percent of their original weight.

Immediately after defrosting, potatoes are pressed by foot, to eliminate constitution water, accelerate drying and produce spallation. It should be performed quickly to avoid fermentation that oxidizes the pulp of the tuber, which partially diminishes the product quality.

After constitution water removal, the humid tubers are piled up to mature for 2 to 3 days, which creates Chuño's characteristic flavour.

The Chuño is placed on straw beds, and dries off taking advantage of solar radiation to achieve 10 percent or less final moisture content needed for good product conservation.

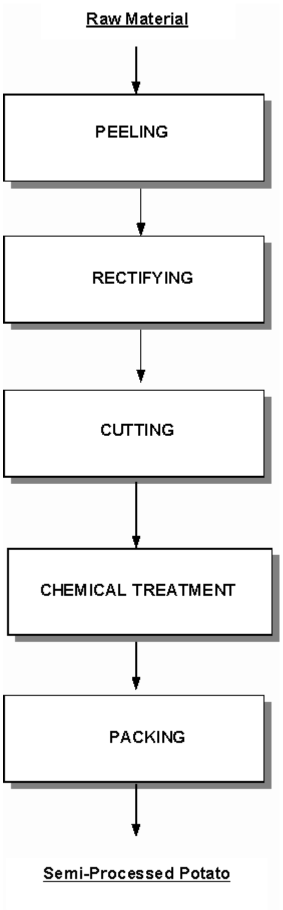
As Chuño dries the product is selected and shelled as other impurities like powder, straw, and others are eliminated. Chuño final yield is 26 percent. The product is packed in jute sacks for storage.

Figure 4:Potato Khaya or Chuño

1.4.2 Industrialized products

Semi-processed Potato (Peeled and Cut)

The steps to derive semi-processed potato are shown here in the Diagram 3.



Description of the Process

Raw material is weighed at time to enter to the plant.

Before washing potatoes are selected by visual inspection. Potatoes that present signs of bruising, stings, rottenness, etc. are eliminated.

Washing removes impurities stuck to the tuber with drinkable water in a rotational potato washer.

The shell is destroyed using an abrasive peeler. The peeled potatoes are deposited in a tub with water to avoid browning.

The "eyes" are extracted manually (Rectified) while the peel remains.

Cutting is carried out with an automatic or semiautomatic potato cutter.

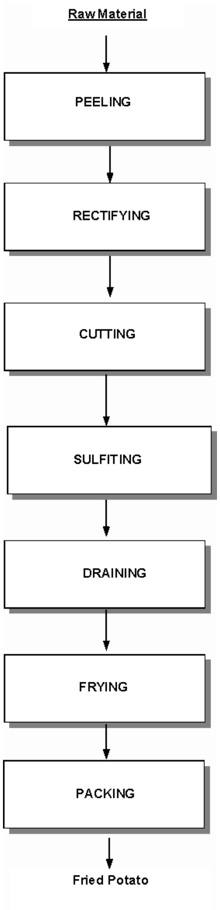
The cut potatoes are deposited in a tub with a solution of sodium bisulfite 1.7 percent where they remain for 30 seconds. After they are drained.

Next the potatoes are weighed and packed in high density polyethylene bags of 5 kg capacity.

Since the production is carried out on request, the storage time of the final product should not be longer than 12 hours.

French Fried Potato (Flakes and French Type)

French fried potato process is outlined here in Diagram 4.

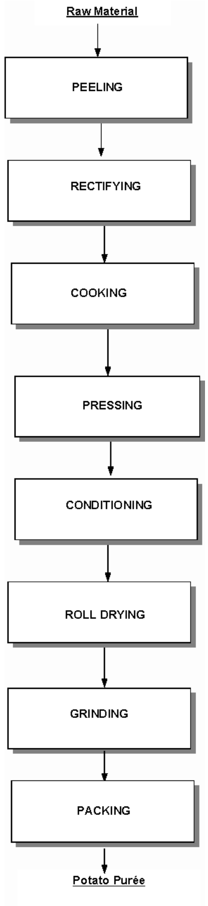


Description of the Process:

Raw tubers are weighed at time they enter the plant.
Before washing, potatoes are selected by visual inspection. The potatoes that present signs of bruising, stings, rottenness, etc. are eliminated.
Washing purges impurities stuck to the tuber with drinking water in a rotational potato washer.
The shell is eliminated using an abrasive peeler. The peeled potatoes are deposited in a tub with water to avoid browning.
The "eyes" are extracted manually (Rectified) leaving the peel.
Cutting of peeled potatoes is accomplished with an automatic or semiautomatic potato cutter.
Cut potatoes are washed with water to remove the starch trapped in the surface. Then the water is drained.
The drained potatoes are fried in vegetable oil to approximately 350 ^{o}F.
Duration of cooking time is a function of the quantity and fryer characteristics.
After cooking, French fries are drained of excess oil.
French fries are seasoned with 2 percent salt and packed in cellophane or polypropylene bags and laminate material. Final yield is approximately 30 percent.

Dehydrated Potato Puree

The process of making potato puree is shown in Diagram 5

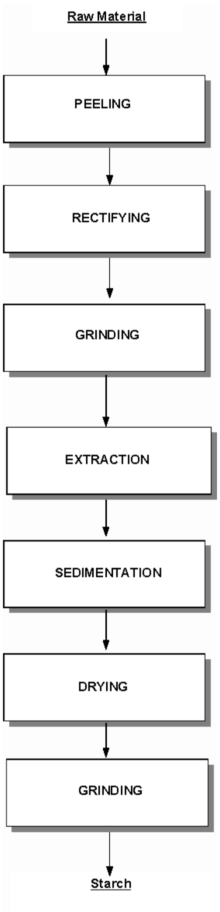


Description of the Process

Raw tubers are weighed at time they enter the plant.
Initial washing can be omitted if a water peeling system is used.
Any commercial method may be applied for peeling: abrasive, vapour, chemical or direct flame peeling.
Peeled potatoes go into a rotating washing machine to remove traces of peel.
The potatoes undergo sulfation by immersion in a solution of sodium bisulfite 0.1-0.2 percent for 5 minutes.
The potatoes pass to a manual rectifier, where peel residuals, "eyes", bruising and spotted parts and other debris are removed.
The potatoes are cut in slices of roughly one half inch thickness.
Then potatoes are pre-cooked in water at 160 ^{o}F for 20 minutes and cooled by immersion in water to below 75 ^{o}F for 20 minutes.
After that tubers are further cooked with vapour at atmospheric pressure for 30-50 minutes. Potatoes should be sufficiently soft to be crushed easily.
Pressing and crushing is carried out in a device called a *Ricer* containing a perforated rotational cylinder upon which rotate two small rollers. The first roller squashes the cooked potato against the cylinder. The second roller forces to the mass to pass through the perforations. An interior screw discharges the product outside of the cylinder.
A simple rotational dryer is used to dry the emerging mass. The mass should contain 20-22 percent solids. It is recommended to apply a vapour pressure of 75-80 psig and a drum speed of 2.5 RPM.
The yield is approximately 22 percent.
It is packed in plastic-coated paper bags or plastic bags, which can fit inside small cardboard or corrugated cardboard boxes.

Potato starch

The steps to make potato starch are shown here in Diagram 6.



Description of the Process:

Raw tubers are weighed when entering the plant.

The potatoes are transported in water flowing toward several washers in series equipped with a water drainage device.

The potatoes are peeled by any method: chemical, abrasive or heat.

Figure 5:Peeled Potato Trimming

The peeled potatoes are disintegrated in a roll mill. It is required to reduce the tubers from a mean diameter of 2 to 2.5 inches until particles can pass through 100 mesh.

The product coming from the mill is sent to a deposit where it is mixed with a solution of SO_2 (1/2 pound of SO_2 by TM of actual starch).

The resulting suspension with density 1.04 is directed toward a separators group constituted by rotational sieves and screen (meshes 80 and 100). The total recovery is of 90.8 percent.

The grout of resulting starch goes by a continuous centrifugal separator where the starch free of protein goes out with a density of 1.05.

The grout coming from the centrifugal goes by a screen (mesh 120) to eliminate the fine pulp that has been able to remain. It exits with density 1.03.

The resulting grout enters to a continuous horizontal centrifuge, where its new density is 1.18.

The humid starch is subjected to the action of a vacuum continuous filter that gives a uniform product with 37 to 41 percent humidity.

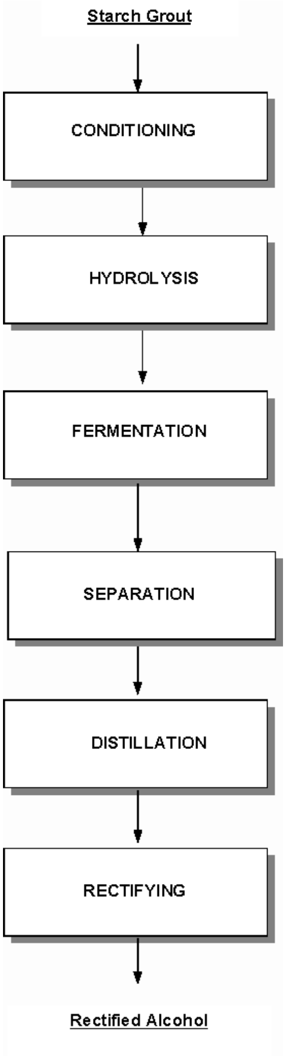
The starch dries off in a drying type flash, with hot air increased to a high temperature for 3 or 4 seconds. The final humidity of the starch should be 12 to 13 percent.

The yield can vary between 10 and 20 percent.

The starch is sifted and packed in multi-sheet paper bags of 50 kg capacity.

Potato alcohol

The process of elaboration of potato alcohol is shown here in the Diagram 7.



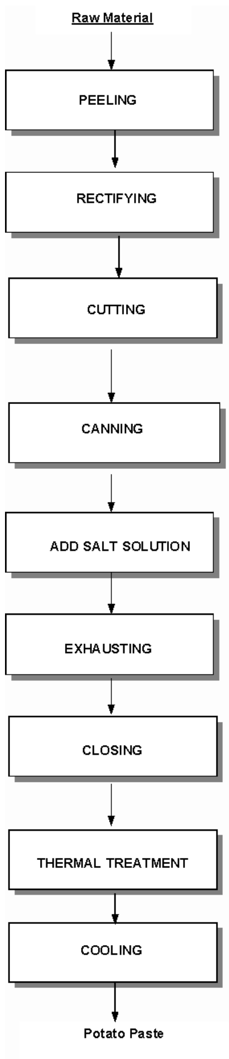
Description of the Process:

Once a gross suspension of starch is obtained, this mixture should be conditioned for acid hydrolysis, with hydrochloric, or enzymatic acid, using concentrated amylases, to attain a sugary must.

Yeast is introduced into the must to begin the process of fermentation. The processes of fermentation and distillation are developed traditionally by lots. The traditional procedure is safe and simple, but takes a lot of time and propagates big quantities of water pollutants.

As an alternative a continuous process is recommended such as the Biostil, where an unique fermenter that allows feeding, vinasse retirement and yeast recycled in continuous form is coupled to an evaporation module and unfolding where goes separating the ethanol.

Diagram 8. Technological Process for Potato Paste



2. Post-Production Operations

2.1 Pre-harvest Operations

Readiness for harvest may be determined by:
Physiological maturity: Crop development stage in which leaves acquire yellow colour, become brittle and begin to dry off the same as foliage. The tubers can separate stolons and their peel presents certain resistance to come off when pressing it with fingers.
Commercial maturity: Around 15 to 20 days after the plant is completely dry. The tubers are denser and their peel doesn't come off.
The crop for consumption should be harvested when it has reached the commercial maturity. For seed, production is advisable to harvest prematurely, accelerating the process of maturity by means of foliage elimination.

Figure 6:Potato Stems in Flowering Stage at Spraying

2.1.2 Sampling

Approximately one month before harvest beginning, a production sampling should be carried out, maintaining consistency by extracting from 10 to 20 plants in a certain area. Weigh tuber production of this sample and relate it to the total surface area to be harvested. This inspections permits estimation of total potato production and consequently, the prospective profits from the crop.
When one observes yellow foliage, this signals that the potato is reaching commercial maturity. Therefore, it is convenient to make samples by taking out tubers in different parts of the field and subjecting them to slight friction with the fingers of the hand. If the peel resists and doesn't peel it indicates that the whole cultivation is mature.

Figure 7:Potato Crop

2.1.3 Foliage Elimination

To achieve greater uniformity in tuber size and to favour peel hardening the foliage cut practice is carried out. This enables:

- One has a firmer peel; the peel doesn't come off to tuber rubbing with fingers;
- Maturity is accelerated;
- Illness, infections by virus and fungi (rust) are avoided, such as contact virus (PVX) and rust when foliage is infected and is prevented to pass to tuber;
- Bigger quantity of potato size seed is obtained.

Foliage elimination can also be done chemically using Gramoxone in two to three litres per hectare dose. This is applied before foliage maturation begins. After foliage drying in 3 to 4 days, tubers should remain in the ground for 10 to 15 days until the peel acquires stability.

Besides accelerating the ripening of the product, this operation has other benefits:

- To avoid insect spread virus infections in seed lots during the last part of the sowing;
- To avoid propagation of the late frost, especially in lots that will be devoted for seed;
- To avoid potato growth too large for commercial size;
- To avoid second growth of potatoes.

The production and potato specific gravity can decrease by foliage cutting. The production losses and potato specific gravity depend on:

- Crop maturity stage at foliage cutting date. The earlier date the bigger is the production loss and potato specific gravity;
- Vigour of the crop at foliage cutting date. Production losses are bigger if the crop is vigorous;
- Interval between foliage cutting and harvest;
- Operation effectiveness. Foliage cutting will stop much more growth quickly than chemical drying.

An experimental finding in Colorado (USA) demonstrated that cutting plant foliage 2 weeks before harvest introduces:

- Fading;
- Decreased percentage of tuber dry weight of more than 2 diameter inches;
- Reduced potato specific gravity.

It is recommended to retire remaining foliage from the field to avoid possible illness and infections.

Figure 8:Potato Stem Cutting

2.2 Harvest

Harvesting should take place when potato tubers are mature. One of the symptoms of maturity is aerial part wilting.

When tubers are mature and ready to be harvested, start digging into the ground with manual traditional tools or mechanical croppers. Parallel with this process check that no tubers are left in the ground, to avoid product waste.

Figure 9:Man in Potato Hand Harvest

As potatoes are harvested in springtime, it is advisable to harvest as soon as they arrive at their natural maturity, before the ground becomes too hot.

Ground humidity grade at harvest date should measure tillage point or slightly drier. It ought not be humid because it can harm potato peel making the product come out too dirty. In case the ground is very loamy at harvest time, the crop should not be dry because the tuber will suffer mechanical damages.

Figure 10:Potato Harvest in Humid Ground

It is suggested that potatoes be taken from furrow to storage areas as soon as possible, to prevent potato damage that can result from sun, heat and wind. Avoid leaving tubers in the open for a long period of time. Any harvest procedure can cause damages if enough care is not exercised in the operation.

Figure 11:Harvested Potatoes on Straw

Figure 12: Hand Harvest of Potato at Dry Stem

Figure 13:Women in Potato Hand Harvest

Prompt harvesting is important, but much more important is to obtain a product free of peelings, cracks, cuts and contusions that drive down its immediate sales value by increasing waste. By increasing waste there is at the same time mounting weight losses. Crudely harvested pptatoes are susceptible to rot in transport or later in storage.

Mechanical damages can be of two types: superficial and internal. The superficial damages (cuts) are more common when the tubers are turgid. If there is success in storing healthy potatoes, losses from rotten tubers are eliminated. This decreases considerably those ruined by dehydration.

Harvest can be made manually with standard hoes, weeding hoes, or semi-automatically and mechanically for significant crops.

Small-scale production gathering is carried out with manual tools. It is necessary to lift tubers carefully to avoid damages and to shake them to remove soil. They are left to dry in the field and once dry are stored in a cool and shady place. Potatoes dedicated to direct consumption should not remain exposed to light for many hours after harvest, because acquire a green colour, unpleasant flavour and can become toxic.

In times of famine it is common for peasants to prematurely by selecting the biggest tubers and burying the plant to allow the tubes to finish their development again.

The main advantages of automated harvest are to reduce the manpower requirements, improve the quality of the tubers, reduce the costs and increase crop profits. However, it is necessary to consider the social aspect of this work, especially where labour is abundant and there are unemployed peasants.

Among the semi-mechanical harvest machines are the ridger implements and the potato plough. This last machine consists of a V-shaped knife that cuts two rows of potatoes.

Among the mechanical harvesters are:

Radial reel snapper: It works with animal traction or couples directly when taking tractor force; it throws tubers in disordered group. What an inconvenience to discover unharvested ridges! Harvesting is slow and a takes place a high percentage of potato are wounded with contusions. It is recommended for humid and heavy grounds, being able to harvest three times more than manual work.

Figure 14:Potato Harvest by Oxen Yoke

Harvester:it consists of a plane ploughing finished in tip of 50-60 cm that is buried up to 20-30 cm by means of a graduate lever. This ploughing lifts the whole ridge, which passes to a chain or inclined plane of iron bars in continuous movement; the ground falls between bars and the tubers remain in an array in the field that makes quick harvesting possible. This machine can be operated by mechanical or animal traction. These are machines suited for one or two ploughings and their yield is two and four daily hectares, respectively.

Harvester-loader: This harvester sometimes deposits the tubers through an apparatus classifier or a band without end in a sack or in a deposit with mounted automatic discharge on the machine. In other cases it deposits them in a car positioned behind or beside the harvester. The ground separation is made by means of an chain drum or a mat siever.

Figure 15:Potato Mechanical Harvest on the Coast

As these machines are huge, the land on which they work should be flat, without furrows, stones or trunks.

The damages constitute the biggest problem with machine harvesting. Potatoes may suffer mechanical damages and/or fading (blue stains) from bruises. The mechanical damages can be as severe as destruction of the potatoes by ploughing, potato compressions among the parts in harvester's movement and tuber bruises caused by excessive force against the metallic parts of the machine. Mechanical damages can be minimized by harvester's good regulation.

Figure 16:Potato Mechanical Harvest on the Andean Uplands

Several measures to impede fading can be taken. To avoid soil employ quick elimination using a sieve. Eliminate hard clods among potatoes. Regulate the chain siever and shakers appropriately. Cover as much as possible with rubber machine metallic parts potentially in contact with tubers. Avoid having the tubers fall from an excessive height.

Tubers are harvested in baskets and are packed into sacks, *huacales* or casks to load them in carts or trucks for transport to warehouses.

2.2.1 Handling and Mechanical Damage

The mechanical damage during harvest depends in a great part of the following:
a) Ground condition: When it is very dry, especially for hard land, contusions, cuts, etc., will take place due to the difficulty of extractor penetration. If it is very humid, the potato peel will be very delicate. The ground should be at tillage, but the product will be dirty with scabs that will later favour rot with bad tuber appearance.
b) Potato harvester type, their adjustment and operation. Whichever variety is used, the operator should observe the following points:

1. Ensure that cuts will be sufficiently deep to prevent cutting the tubers.
2. Lifts enough quantity of ground so potatoes will not be not ruined in their journey.
3. Maintain stable slow cropper speed along the furrow to evade violent agitation of of elevator chains. Reduce the speed more when the ground is dry.

2.2.2 Sun Heat Exposure Damage

These damages are largely reduced in mature potatoes, because just peelings are the critical points where more damages take place quickly.

Exposure from sun heat causes rotting. This happens in only 2 or 3 days. These damages can take place as a result of direct contact with the sun at the time of being harvested. This may also occur before harvesting when the plant is dead or cut.

- The damages are proportional at the time of sun heat exposure after potatoes are harvested.
- If after sun damage the potato is stored in temperatures from 10 to 15.5° C it will not rot. At 21°C, there is little rotting. At 32° C, there is more rotting.
- In storage, the incidence of rot is higher for potatoes exposed to higher temperatures on the surface.
- Potatoes harvested in hot weather rot more than those removed in more temperate days.
- A half hour or an hour of sun is more dangerous before noon than between 2 to 4 of the afternoon.
- Rottenness is found in cuts, contusions, peelings or sites of secretions.
- When air temperature is 32°C or higher, it is not advisable to dry potatoes. Air temperature of 26.5°C or less is correct.
- It is recommended not to expose potatoes to air and sun for more than 15 minutes on days when temperatures hover near 32°C in shade.

2.3 Transport

2.3.1 Transport

It should be completed rapidly to avoid sun damage.
The containers that are recommended are the bottom rigid and flat baskets, padded wire baskets, or padded pails. Transferring tubers in sacks generate a larger percentage of damages unless the work is done very carefully.

2.3.2 Transport in Trucks

Thus crop handling inside the field or transport to exterior with trucks or trailers has great importance. There are mechanical damages to potatoes before leaving field. These damages will become evident later at storage. To avoid mechanical damages in all these operations, it is necessary to convince the personnel to utilize proper handling:

1. Potatoes should be placed inside containers and not thrown inside them.

2. Truck drivers should not stand on potato sacks but on the platform of the truck.

3. Full sacks of potatoes should be placed in position and not thrown at truck loading and discharging.

The use of soft linings is recommended in trailers and trucks that transport potatoes. A straw bed should be used in trucks, or pads can be made with sewn sacks half filled with straw. These pads go first to line the truck platform, where the crop will be laid.The impact bruising during the transfer will be significantly reduced.
It is also necessary to securely tie the load to avoid movement of sacks, resulting in bruising.
Another point is that potatoes should be handled the absolute minimum number of times possible. Clearly, damage often proportional to the number of times that potatoes are transferred.
All labour involved with potato handling should be supervised carefully to guarantee an appropriate operation.
Frequent detailed inspection is needed at different process steps, to detect and to correct damages that take place.

Figure 17:Potato Truck Transport

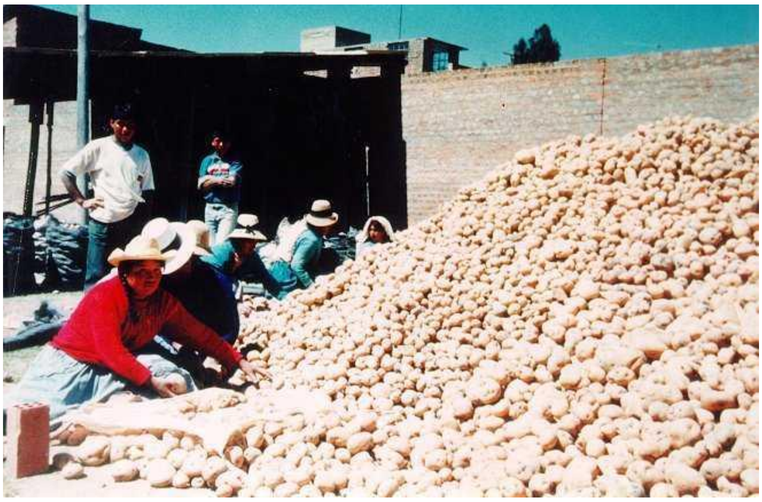
2.4 Threshing

2.4.1 Sorting and grading

2.4.1.1 Sorting

During sorting, ground, stones, vegetal wastes, cut or rotten tubers are separated. Sorting of harvested tubers consists of selecting tubers that show symptoms of plague or illness. Sorting is achieved manually or with sorting machines. The second case offers better advantages as for efficiency and economy. Whichever method is chosen, potato contusions or bruising are avoided. The quality of stored tubers is the most important factor that affects technical output of any storage system. To carry out this practice, potato tubers should be mature or previously cured.

Figure 18:Potato Sorting and Grading



2.4.1.2 Curing or Conditioning

Potato tuber curing consists of conditioning them during a period of several days (1 to 2 weeks) in a warehouse or deposit with good ventilation and appropriate temperature. This allows wound healing or lesion suberization.

Curing is an indispensable requirement for successful tuber conservation. It is appropriate to apply curing after harvest. This is carried out by maintaining tubers at temperatures from 16°C to 21°C with 90 percent relative humidity during approximately 10 to 15 days. During this phase healing of wounds caused by potato handling will take place while avoiding water loss and fungous invasion. This wound healing is effected by the production of new layers of cells under wounds. The cell layers will become corklike. When healing is finished, the wound area will have a thick film than will serve as a protective layer.

Temperature, humidity and curing duration period should be modified for sick or damaged potatoes. Suberization temperatures will promote microorganisms development of rotten and tuber soft rupture. The potatoes affected with rotten and bacterial soft freeze will decay and will increase warehouse humidity. In this case, the relative humidity should be maintained as low as possible to prevent additional rupture.

There is no consensus regarding the ventilation regime that should be used during the curing period. Softening or condensation in the exposed tubers happens when they are fresher than those inside the pile. A small quantity of free water is generally harmless, but any excess of humidity will propitiate soft rotten areas. Continuous ventilation is recommended when condensation is present.

An alternative stage that the peasants carry out prior to potato storage is placing the tubers on a straw and ***muña*** bed in a walled place. Tubers are exposed to environment for two weeks to enable the worms collected with the harvest to fall and die after contacting the penetrating scent emanated from ***muña***.
Also, Andean uplands climate conditions are at or near the range of temperature and relative humidity that allow appropriate wound healing or curing. These are parameters corresponding to temperatures from 15 to 21°C and humidity measurements between 85-95 percent during approximately 10 to 15 days.

2.4.1.3 Grading

Grading refers to the process of classifying tubers according to its size. The size of grading tubers will agree with the specifications dictated by seed potato standards of each country. These are the same guidelines that also establish norms for pack characteristics and for pertinent information contained on the label.
The purpose of grading for quality is to facilitate marketing, simplifying for product selection for wholesalers..
Among the benefits that grading provides to the producer are:

- It stimulates production of potato superior qualities of more economic value;
- It facilitates product concentration;
- It allows establishment of price differences in function of quality;
- It reduces marketing costs when suppressing product movement of low quality and smaller price;
- It simplifies sales based on quality. In case of potato seed, the quality should not only be judged by appearance, but rather its antecedents should be known detailing identity, sanity, origin and handling.
- In the Peru, potato for its sale will be classified as white potato, potato colour and yellow potato.

The white potato and the potato colour are classified in turn into A and B grades, according to their dry matter content.
1. White Potato: Has white or creamy peel, can have blue or rosy stains, white, blue or reddish eyes, white or creamy pulp and a rounded or snub form. The varieties considered as White Potato are:
Class A: Tomasa Condemayta, Antarqui, Revolucion, Yungay, Renovacion, Chata Blanca, Coyota, Mantaro, etc.
Class B: Ticahuasi
2. Colour Potato: Has purple, reddish or rosy peel, eyes of peel colour, white or creamy pulp, with a blue or purple halo and varied form.
Class A: Huayro (long or rosy), Tarmeña Rosada, etc.
Class B: Mariva, Cuzco, Compis, etc.
Yellow Potato:
A potato has peel, eyes and pulp of yellow colour. Each one of these types will be classified according to their size, aspect and sanity, using the following commercial categories:

- Extra grade
- First grade
- Second grade

2.4.1.4 Grades for Consumption

Potatoes for their classification in grades that are indicated next, will belong to the same variety and to be in an appropriate maturity stage (verdant won't be), not being accepted potatoes that present rotten neither scents or flavours strange (residuals from insecticides, fertilizers, etc.)

1. Extra Grade: Minimum sizes
a. White Potato 8 cm wide
b. Colour Potato 7.5 cm wide
c. Yellow Potato 6 cm wide

Aspect and Sanity: In this grade, potatoes won't present perforations or galleries, wounded or courts, neither cracks. Verdant potatoes won't be accepted with sprouting beginning or deform. It will be accepted until 5 percent of potatoes with contusions.

2. First Grade: Minimum sizes
a. White Potato 5.5 cm wide
b. Colour Potato 5 cm wide
c. Yellow Potato 4 cm wide

Aspect and Sanity: In this grade 5 percent of potatoes will be allowed with perforations or galleries, 5 percent with deformations, 3 percent with wounded or courts and 10 percent with contusions. Potatoes verdant or in sprouting won't be allowed.

3. Second Grade: Minimum sizes
a. White Potato 8 cm wide
b. Colour Potato 7.5 cm wide
c. Yellow Potato 6 cm wide

Aspect and Sanity: In this grade, 10 percent will be allowed with perforations or galleries, 5 percent with wounded or courts, 10 percent with healing and 15 percent with contusions. It will be allowed 5 percent verdant, 3 percent of sprouted potatoes and 10 percent with deformations.

In Table 12 permissible tolerances are shown for different types of damage observed in potatoes.

Table 12: Tolerances for Different Types of Damage According to Potato Grade.

Damage Type	Quality		
	Extra %	First %	Second %
1. Plague Damage Bites Holes and burrows	0	5	10
2.Plant Pathological Damages Dry rottenness Wet rottenness	0 0	5 0	10 0
3. Mechanical Damages Wounds or cuts Wound healing Bruising	0 0 5	3 5 10	5 10 15
4.Physiological Damages Splitting	0	10	15

Source: Min. de Agricultura y Alimentación (1979).
Complementary rules:
1. It will be allowed that 10 percent of product weight is of size different to suitable for each grade.
2. Tolerances allowed for different damages or defects are refereed to product weight percentage.
3. It will be considered that a potato can present damages and different defects that will be graded individually.
4. Product grade qualification that has been stored will be made with the same requirements settled down in the present norm.
5. Potato grade commercial value considered in each type, it would be larger, for the extra grade potatoes.
6. The potatoes that cannot be classified in the suitable grades will be considered outside of Standard, and their sale will be carried out according to agreement between Wholesaler and Buyer, should be lower price than second grade.

2.4.3.2 Grading for Seed

a. By weight:
Extra : Tubers of 81 g or larger
First : Tubers among 60 to 80 g
Second : Tubers among 40 g to 59 g
Third : Tubers among 20 g to 39 g
b. For their form and diameter, it corresponds to their biggest traverse dimension expressed in millimetres:
For long and long oval tubers:
Extra : Tubers of 80 mm or bigger
First : Tubers among 60 to 70 mm
Second : Tubers among 45 to 59 mm
Third : Tubers among 28 to 44 mm

2.5 Drying

Please refer to Section 2.4.1.2 Curing or conditioning for details on reduction of moisture content for potatoes. Actual drying of tubers for food processing is addressed under secondary products discussed in Section 1.4.

2.6 Cleaning

2.6.1 Cleaning and transport

In Washington State (USA), there was an experiment with potatoes that passed directly from harvester-loader machine to a truck provided with a tank full of sodium hypochlorite solution that washed them, whitened, and avoided impact bruises damage.
It has been that potatoes harvested in water have less blue stains and they are much more faded that tubers bulk harvested in cars or trucks; water harvest also reduces external damage. Water potato unloading when arriving at the warehouse reduces damages and eliminates the necessity to move transporters and cranes.
The tubers once arrived to the reception area they pass to conveyor belt that drive them until washing machines.
The washers consist on a tank system in which potatoes are sunk so soon arrive from field, or wash by means of a fine rain or pressure rain that avoids the soft rottenness contamination that frequently happens in tanks. This machine gives better appearance to the tubers and facilitates sorting.
From the washer potatoes pass through in a conveyor belt through an air current at 65°C for 4 minutes to remove excess humidity. If atmosphere relative humidity is lower than 70 percent, it is possible to pack still humid tubers.

Figure 19:Potato Mechanical Washing

2.7 Packaging

For potato conservation, whether under refrigeration or by using sprouting inhibitors, it is necessary to utilize packages that allow good air circulation and easy handling. It is recommended to use 50 kg sacks of open weft where superior air circulation is achieved. Boxes of 50 kg or 100 kg capacity are recommended to pack the potato sacks featuring lateral openings for a good airflow.

Figure 20:*Potato Hand Packing in Propylene Sacks*

Figure 21:*Potato Mechanical Packing*

2.8 Storage

Storage is only part of total production system. The losses that are presented in this stage are affected by numerous previous factors, at harvest and pre-harvest that influence considerably tuber preservation.

Potato varieties present diverse resistance characteristics to mechanical damage in at harvest and by handling, as well as plague resistance, and rest period length and sprouting.

The different cultural practices affect physical conditions, and physiologic stage and sanitary of tuber at harvest time.

To reduce lesions risk and illnesses, it is advisable to eliminate foliage 2 or 3 weeks before harvest. It is preferable to use a contact herbicide, because cutting is not able to eliminate whole foliage, and it can propitiate appearance of some illnesses that ending affecting to tubers.

If foliage is not eliminated, it is necessary to delay harvest until tubers are very mature.

After harvest, it is necessary to protect tubers from sun exposition, since intense sunlight became tubers verdant, diminishing quality for consumption.

It is requirement for a good preservation that potatoes are dry. If they are humid, fungi and bacteria that cause illnesses and rottenness will easily attack them. For this reason, humid potatoes should be dried, by means of a quick circulation of environmental air.

It is necessary tuber selection to only store products of more quality, without impurities neither illnesses.
In storage preparatory phase, it is indispensable requirement that potato been cured.
The seed that will be stored should be disinfected after being cured and selected.
For potato preservation for direct consumption, sprouting inhibitors should be applied to extend potato shelf life of the product. Usually No Brotan is used in a dosage of one kilo per tuber tonne.
It is convenient to use a repellent against plagues. In the Andean uplands, it is common to use ***muña***. A layer of this grass is placed under potato pile, and is continued with intercalated layers each 30 cm.
Healthy potatoes should only be stored, without damages neither decay visible signs. The potatoes dedicated to direct consumption or elaboration processes should be stored in the darkness to avoid that become green. Those for sowing are stored with diffuse light to promote the development of several vigorous sprouts in each tuber.
Due to the lack of warehouses for potato harvest preservation, most producers are forced to sale immediately their products after harvest, loosing their profits with rising economic detriment.
Appropriate facilities for good preservation of this tuber, will allow a regular supply to wholesale markets and a better product use by producers.

Figure 22:Potato Traditional Storage

2.8.1 Factors that Affect Storage Length

The potato is a living tissue that is subject to physiologic processes which induces to quantitative and qualitative changes in its physiologic behaviour. Among these processes, have the following:

- **Transpiration**: Quantitatively it is the most important and it depends on the gradient of temperature between potato pile and environmental air, relative humidity in the warehouse and tuber peel permeability.
- **Respiration**: It is affected mainly by pile potato temperature. Because of the respiration, potato tuber gets lost dry matter, that is to say that it diminishes the quality of the tuber.
- **Sprouting:** It contributes to weight and quality losses. A high temperature will favour sprouting beginning when finishing dormancy period.
- **Illnesses:** The illness occurrence in the storage depends on degree of initial contamination and temperature conditions, relative humidity and storage length.

The storage objective is to control these processes to maintain quality and to minimize losses tubers weight. Factors that should be controlled in storage are the followings:

- Temperature
- Relative humidity
- Ventilation
- Light

2.8.2 Direct Consumption Storage

It should be executed in dark atmospheres, on a ground of ***muña***, with good ventilation, low temperatures (6 to 8 centigrade degrees) and high relative humidity (85 to 90 percent).
To achieve tuber preservation by 5 to 6 months, it is recommended to use the product ***No Brotan***, to the dosage of 100 gr./tonne of potato, applied to each layer 10 centimetres high of potato stored. Storage should not overcome 2 meters height.
The potato tuber is a living tissue, with such physiologic actions as the respiration and transpiration. For respiration, effect tubers consume oxygen, dry matter, producing carbon dioxide, water and heat. For transpiration effect that is proportional to the deficit of pressure of vapour (VPA), tubers become dehydrated.
An increment of temperature produces higher transpiration and respiration, what favours a quicker dehydration, quick sprouting and favourable environment for proliferation of microorganisms. From this point the importance, that heat produced by stored tubers should be extracted permanently via natural or forced ventilation, with the purpose to reduce physiologic processes velocity and to minimize losses by dehydration, sprouting and rottenness.

2.8.3 Seed Storage

It is made in warehouses with diffuse light, with good ventilation, low temperatures (4 to 5 centigrade degrees) and high relative humidity (85 to 90 percent).
Basically, it consists on storing potato seed in platforms or bookcases or boxes, in such a way that the tuber doesn't receive direct light but in indirect or diffuse way. It must allow appropriate greening and good ventilation.
The main effects that produce diffuse light in tubers are the following:

Greening

The skin and pulp of the tubers form a green coloration, being of production of chlorophyll and solanin, those that are of bitter flavour and they can end up being toxic. This is achieved with storage process to diffuse light.
Break of apical dormancy

The vast majority of potato varieties have a positive response to break apical dormancy. This consists in that young buds from apex begin to grow while growth of old buds is suspended. In consequence, a tuber stored on diffuse light system will have higher bud number that tuber stored under darkness conditions.
Production of small, strong and vigorous sprouts
For darkness storage system is necessary a break of sprout apical before sowing. However, in diffuse light system, it is not necessary to carry out the disbuding before sowing
It favours the appearance of radicle primordia.
The basic knowledge of these factors will allow an appropriate storage handling.
Consequently, it can have a vigorous seed for effect of diffuse light.

2.8.4 Storage Methods

There is not a storage method that is the most effective for potato handling. Method selection depends on technical, social, economic and financial factors.
In general, the simple or rustic warehouses are cheaper and in many cases can tolerate a higher losses level that in more expensive storage systems.
For selection of storage method should be considered in addition technical and economic aspects, their acceptance by consumer and producer.
A classification of storage methods based on their physical location is considered: In field ground, by means of harvest delaying.
In simple piles or heaps covered with straw and ground.
In specially built or multiple purpose warehouses.

2.8.4.1 Harvest Delaying

Harvest delaying or storage into ground, consist on leaving potato into ground after foliage has been eliminated by a natural process, or are induced by cutting or by using herbicides. It is the simplest method and can be used for 3 months, depending on variety, climate, ground, illnesses and plagues.
They can only be considered varieties that have a period of rest of at least three months.
The climate should be cold, with a temperature that fluctuates between 0 and 15°C.
The ground should be loamy or sandy. It should not remain humid for several hours, because it could propitiate tuber rottenness.
The main advantages of the storage into ground are:

- Low cost
- It allows a careful harvest
- Potato has a fresher appearance that potato stored in warehouses.

2.8.4.2 Heaps or Piles

They are simple structures that can be employed to store potato in field. It is useful when one doesn't want to invest in infrastructures and when the labour cost is not very significant.
The system consists on to accommodate tubers in heaps and to cover them with potato layers and ground. Numerous modifications of the method exist. Method main advantages are their low cost and their adaptability to numerous situations. It is used so much by small farmers, as for farmers that work to great scale.
The excessive losses of this storage system come from rottenness, resulting from humidity penetration in heaps.
It is necessary to use sprouting inhibitors if tubers will be stored by for higher time to natural rest period.
Among method variations, one has heaps holes or piles type, covered with straw, or straw and ground, with or without ventilation duct, etc.

2.8.4.3 Specially Built or Multiple Purpose Warehouses

Premises of multiple purposes are constructions commonly used to store potato. They should maid used for other purposes, and for it are found less efficient for storage. They can be from one or several rooms of farmer's house, to general deposits of multiple purposes, inclusive with refrigeration. They are always less effective than specific buildings to store potato.
For the design of a warehouse specifically for potato, it should be defined the size that will be in function of potato quantity of potato that will store at first. It should be decided if it will consist of a single or several rooms, if the ventilation will convection or forced air and if it will provide refrigeration.
Inside warehouse, the tubers can be stored to bulk, in boxes or sacks.
The boxes are particularly useful when are stored in one room several harvests. The best thing is to use boxes of 1/2 tonne or 1 tonne of capacity. It is required of a mechanical handling.
The sacks don't offer bigger advantages with regard to the storage to bulk or in boxes. The sacks of lighter material and fabric that is more open are better than those of heavier material and stronger fabric do.
In the storage to bulk should take care about pile height that will be in function of room temperature, and ventilation conditions and refrigeration, if there were them.
Another important element in warehouse design is the relationship area/volume that affects heat transfer flow.
Specially built warehouses vary from small rustic warehouses of low cost, going by warehouses intermediate with natural ventilation, to warehouses of great capacity with forced ventilation and refrigeration.

2.8.5 Storage Types

2.8.5.1 Silos

Potato storage system in silos is one of the most traditional. It is used thoroughly in the South region of Argentina and Chile, it has been taken to Europe it is of common use in Great Britain, Ireland, Germany, Poland, among others.
The silo, in general, gets ready especially in a land site in that has been the crop to avoid transport, in the extensive farms. The potato is deposited in a gutter, or on ground surface, being the latter system more in use. It is built an array of potatoes of more or less 2 m base, 1 m high and of a length variable, 15, 20, 30 or more meters. Once deposited potatoes are cover with some protective vegetable material-canes and straw of corn or of wheat-with a thickness of 5-10 cm covering later with ground; each 2 to 5 m portholes are placed to allow certain air circulation. In Balcarce potatoes stay under these conditions until the next sowing. It is considered losses of 10-30 percent during preservation period.
In Europe, the great technological changes occurred in the last decades in agriculture and social field conditions gradually conduce to silo elimination.
Wages that are used to keep the potato in silos are not very expensive, but guard's method in warehouses allows a quicker selection and this doesn't depend on the conditions of time; besides giving permanent labour to agricultural workers of a farm in rainy periods.
The silo used in the potato main region Argentinean, the southeast of Buenos Aires County, is the pile; a simple potato heap on ground surface and that is covered with a straw layer. It has been introduced certain modifications to this low cost and primitive system, for example silos semi-underground with respiration portholes.

2.8.5.2 Ambient Temperature Warehouses

This is the most frequent method used in Latin America. Potatoes are placed up to a height from 1.5 to 3 m; the storage conditions depend mainly on local temperature.
With a temperature higher than 15°C of potato is not preserved more than 3 months because shows general sprouting by ending rest normal period of tubers. When choosing a warehouse for potatoes it should be considered the readiness, that can offers this for load and unload operations. It is preferable to make load from the roof or from a second floor, taking advantage of some land difference, by means of belt conveyors from the cars or trucks, and unloading from first floor.

2.8.5.3 Refrigerated Warehouses

Potato culinary quality, palatability and composition are influenced markedly by storage temperature.
In general, storage at +4°C or fewer give for result an increase in the sweet flavour and changes in consistency and colour.
a. Enough ventilation through barn, from bottom to top, to extract corrupted air and excess of humidity.
b. To avoid the light for potato-direct consumption, in order to prevent the solanin development.
c. The tubers should stay dry and mud free. A humidity or mud excess increases heat quantity on recently stored potatoes and it causes the black heart.
d. All damaged and sick potatoes should be eliminated before storage.
e. Not to store potatoes in barns of more than 4 m depth and to provide them of ventilation grills, not only lateral but on the ground.
f. Barclay and McNair (1974) studied the loss of weight of two potato varieties stored under the best conditions. It was experienced with a potato lot of variety Kennebec and another lot similar of the variety Netted Gem, placed in boxes and fixed in a design of blocks not matched in two warehouses, during 8 months.
In Table 13, the results of the experiment are shown.

Table 13. Percentage of Total Weight Loss during Storage Length

Box N°	Kennebec		Netted Gam	
	Warehouse1	Warehouse 2	Warehouse 1	Warehouse 2
1	7.1	4.5	3.6	2.5
2	6.8	5.0	3.6	2.5
3	5.6	4.9	3.6	2.5
4	6.8	5.2	3.6	2.5
5	4.3	4.5	3.6	2.9
6	5.0	4.6	3.6	2.9
7	6.6	6.4	3.6	2.9
8	5.3	4.7	3.6	2.9
9	5.0	5.5	3.6	2.7
10	5.0	5.5	3.6	2.9
Mean	5.8	5.1	3.6	2.7

Source: Barclay and McNair, 1974
Warehouse N°1 was equipped with automatic ventilation with circulation of lateral air by walls, temperature was constant at 5.6° C with 92 percent relative humidity, achieved by

wetting cement floor continually. Warehouse N°2 were equipped with automatic ventilation, with air circulation by means of ducts opened up in the floor and with an automatic humidifier that maintained relative humidity in 92 percent. Temperature was 4.4°C. Each box was weighed for intervals of one month and half. Losses were calculated in percentage for the storage period and the mean difference was compared by Student t test.
It was registered a loss of 5.8 and 5.1 percent for Kennebec and 3.6 and 2.7 percent for Netted Gem in the warehouse N°1 and in the warehouse N°2, respectively. It is seen that losses in warehouse N°1 went higher to those happened in N° 2, in both potato varieties.
If one makes an economic estimate with this 5.8 percent weight loss to 100 boxes of 1/2 tonne of capacity each with potatoes prices of US $250 tonne on tonne farm, one will have a loss of 2.9 tonne, that is to say of US $725.00.

2.8.5.4 Warehouses with Night Cooled Air

This system developed in Holland (Potato Preservation) it is based in that, during the coldest hours (night), it is possible to blow external cold air by means of fans through stored potatoes.
External heat influence should be the less possible thing to retain low temperatures that can be reached by means of warehouse night cooling.
At warehouse floor, ducts are made that are covered with wood. Channel is communicated with external air by means of a hole of fan diameter size. Through ventilation channel, there are wooden laths grills, each one of which are of an appropriate length to be lift easily and has a separation so that potatoes that are deposited above don't pass through holes while the air can circulate by them. In roof, exist several holes for air exit that can close in their inferior part by some small wooden floodgates.
The interior height of these warehouses is about 4 m. To make ventilation the external shutters and roof sliding doors open up, corresponding to air escape holes located there. Fan is started and cold air goes by feeding channel and by wooden lath grills through potatoes. Theoretically this cold air ventilates each potato tuber, since 1/3 part of potato heap is empty space and 2/3 parts are potato mass. In fact, thousands of small channels through which air finds its road from bottom to top; air lightly heated is liberates later in potato heap superior parts and abandons warehouse through roof openings and top windows. In addition, it is continued this way with ventilation until potato temperature is equal to exterior ambient.

2.8.5.5 Glass Warehouses

In Europe glass warehouses are used, similar to greenhouses, specially built to store the potatoes, high quality seeds during winter time; walls and roof parts are made up of lined glass wired in double layer; air that exists between both walls serves as insulator. To avoid that temperature increase too much, it is also applied isolation material.
In glass warehouses, you can only preserve potatoes in trays, since light should penetrate through tubers. For such a reason not very deep trays are used, as well as among trays piles. It is also necessary not to fill them until border, because this would also impede air penetration. If tubers of small size are stored, it only suits to put thin layers in trays.
It can happen that in spite of preservation to light it has excessive germination; in this case, it is necessary to pour trays content in other trays, so that bottom tubers change place and be up. From time to time, it will be necessary to change interior piles and external ones to each other.
This preservation system is one of the most expensive because potatoes occupy a great volume being in trays. Only are used by farms specialized in seed production.

2.8.5.6 Warehouses with Sprout Inhibitors

The potato tubers for consumption deposited in warehouses refrigerators or in warehouses to ambient temperature, predominant in potato Latin American regions (10 to 25°C), can be treated with sprouting inhibitors chemicals to prolong storage period.
In Table 14 most common potato, sprouting inhibitors are shown.

Table 14. Potato Sprouting Inhibitors

Name	**Method**	**Observations**
MH30 Maleic hydroxide	Sprinkle 4 kg i.e., to potato crop field before harvest.	4-6 weeks before harvest.
CIPC Isopropil - N Chlorfenilcarbamate (No Brotan)[1]	Applied on warehouses after potatoes being cured. Not use this product when in the same warehouse is stored seeds. Sprinkle also can be done in grading and selection operation.	Effectiveness is reduced in dirty potatoes. Act as gas, 10 g/tonne of potatoes.
TCNB Tetrachloro-nitrobenzene	In powder at 6 percent. Applied 120 g/tonne i.e.	It is a weak inhibitor.
EMANA Estermetil naftalenacetic acid	30 g/tonne	Avoid periderm formation, which limit its use.

Source: Alvaro Montalvo, 1984 [1]CIPC NO BROTAN is the only one, which is used commercially in Peru.

2.8.6 Warehouses More Used at Peru Andean Uplands

2.8.6.1 Traditional Storage

For many years, potato storage in the Andean uplands is carried out according to farmers' uses. The potato that is harvested is sold for direct consumption and, at its time, as seed; each small or medium farmer preserve himself potato that would use by family consumption and as seed for next sowing. In addition, a small part of the crop can be used by small farmers to pay labourers or to sell whenever they need cash for purchases. This reserve could also cover demand that occurs in other producer areas when harvest time is ending, allowing continuous supply of regional markets. The storage for sale in the future is not given. This alternative is risky due to probability that it doesn't happen a enough potato price increase so that it covers storage cost, weight and quality losses occurrence, besides the farmer's necessity of paying its debts, or having cash liquidity at harvest time.
Potato weight or quality losses have relationship with tubers placement in heaps or barns and with environmental conditions that are presented inside and outside of warehouse. It is known that a tonne of tubers prepared in heaps or piles has near 0.5 m3 of air into them.
The tubers in the barn or heap should not have ground because can affect internal heat transfer rate toward air (resistance to the current of air could increase); on the other hand, sprout growth among tubers spaces also increases resistance to airflow. Air circulation (natural or forced), it is necessary to remove heat, to evacuate CO2, water and to supply oxygen. Ventilation that increases necessary air exchange will increase water loss inevitably.

__2.8.6.2 Warehouses Inside Farmer House__

Next, it is a detailed description about storage ways used by peasants in the Peru Andean uplands:

Troques, is quite employed in Cusco; it consists on storing potato on straw in dark and fresh rooms.

Taqe: Also used to store grains; it is a warehouse of circular form of 1.5 m diameter by 1 m height woven of wheat or barley straw. The ***taqe*** generally settles in dark rooms.

Kawito is a warehouse type frequently used in Paucartambo-Cusco; this is made with shelves of eucalyptus branches and straw or with adobes in which potato seed and for direct consumption is stored covered with straw at bottom part; in the top part is stored grains.

Suncho is a variation of the ***kawito*** in which shelves are wooden.

Chaclanka is a warehouse used in Mantaro valley. The ***chaclanka*** is a specially built platform through room beams on first floor. It is made of Eucalyptus trunks on which potato covered with a straw layer is spread. In this warehouse, it is only stored direct consumption potato.

The ***llutasca*** used in Corata-Puno, is a warehouse in which potato is gathered supporting it on wall then covered it with straw and ground storing it by 4 or 5 months.

__2.5.6.3 Warehouses Outside Farmer House__

The ***pinakancha***, used in the department of Cusco; consists on placing potato among wall fences forming heaps that cover with straw. The ***pirhua*** is a ***pinakancha*** variation; it is a circular warehouse made of straw tied with ropes and where potato can be stored in the bleakness from May through November.

The ***qoto***, is another variant of the ***pinakancha*** where seed potato is placed in heaps and covered with straw. Each heap contains only 30-50 kilos of potato.

In the ***pampasc'a,*** potato tubers stay underground in a 4x 1.5 m rectangular hole and whose depth is a man height; bottom is covered with stones on which ***ichu*** is placed. The ***ichu*** is also placed between wall and tubers; at the end, tubers are covered with ***ichu*** and ground levelling with soil. This storage form is called ***pogullo*** or ***huaco*** in Mantaro valley.

A variant of ***pampasc'a*** is ***montonasq'a*** which consists on forming large tuber heaps that are covered with ***ichu*** and ground, that resembles the ***pitra*** and that it is used in Mantaro valley.

The ***shunto*** is used at higher altitudes, a method that consists on extending potato on field covering with ***ichu*** straw. Superficial potatoes possibly freeze, appear black and dry off forming a waterproof cover that protects those underneath.

Another form of storing potato in Matachico (Jauja, Junín) it is the ***troja***system. The ***troja*** is a weave of wheat shafts with ***ichu*** ropes that closes in cylinder form placing alternately in its interior ***muña*** layers and potato; at the end a layer of ***muña*** is placed.

Storage in holes is used in Chamis-Cajamarca. The entrance of a hole is narrower in this warehouse. It consists of placing ***ichu*** straw and branches of ***hanca***(***muña***) at the bottom and along the walls. It is filled alternately with layers of potato and ***chanca*** branches until contents are covered at the end with straw and soil arriving at the ground level. Elder, ***marco*** and ***molle*** branches are also used. If the potato risks attack by pests, ash is sprinkled.

In Chamis-Cajamarca, named ***troja*** to seeds storage in a small house built of adobe or ***quincha*** with a straw roof of straw of three floors or levels. First underground level or semiunderground level is used as a ventilation chamber and to store tubers or firewood. Second level or intermission presents two dark chambers to store up to 80 ***arrobas***, the third level is a house entrance, which communicates with the second level.

2.8.7 Storage Losses

Losses during the storage are affected so much by physiologic tuber condition, mechanical damage suffered during harvest and handling, as well as by storage conditions Mechanical damage (cuts and contusions) facilitates invasion and development of microorganisms that cause illnesses and rottenness.
In Table 15 weight and rottenness, losses are shown during storage of Russet Burbank potato variety, considering different physical damage characteristics when entering warehouse.
The physical damage causes a tuber stress condition, what originates an increment in potato tuber respiration activity, with a weight loss increase.

Table 15. Different types of damages effect on losses during Russell Burbank variety storage.

	Losses %		
Damage Class	**In weight**	**By rottenness**	**Totals**
Cuts	6.5	59.9	66.4
Strong bruising	5.8	45.2	51
Light bruising	2.5	1.5	4
Moderate bruising	2.8	20.5	23.3
Healthy	1.9	0	1.9

Source: Grandon Martín, 1982.
From Table 15 it is appreciated that weight loss shows a lineal relationship with regard to nature or magnitude of physical damage.
On the other hand, losses by rottenness are increased exponentially with regard to magnitude of physical damage. This way, we have that while in healthy potatoes with light contusions losses are insignificant (0 and 1.5 percent, respectively), potatoes with contusions and cuts medium or strong present losses of 20.5, 45.2, 59.9 percent for rottenness, respectively.
In conclusion, it is necessary to reduce tubers physical damage to minimize losses during storage.
Plagues existence, in addition to losses that originate it, can be constituted in a vector for microorganisms invasion. For it, invasion should be prevented from field and warehouses and implements used for transport should be fumigated.
To control losses by microorganisms invasion, resistant varieties should be chosen, to use seed of good sanitary quality, to make a good crop handling, applying appropriate techniques of harvest and post-harvest.
In Table 16 total losses in potato storage for seed, in different types of warehouses in the Peru are shown.

Table 16. Storage* Total Losses Comparison in a Warehouse Range for Potato Seed-Peru.

WAREHOUSE TYPE	**STORAGE LOSS (% INITIAL WEIGHT)**		
	1 MONTH	**3 MONTHS**	**5 MONTHS**
Cold room at 4°C	1.3	1.7	4.8
Adobe warehouse with natural ventilation	1.5	6.5	12.3
Wooden rustic warehouse	2.7	9.5	14.4
Field pile with straw and cornstalk cover	3.2	7.9	14.1
Field pile with straw and ground cover	2.8	14.2	22.3
House farmer	4	10.5	15.2

*Source: CIP, 1980. * It includes loss by evaporation, sprouting and illnesses. Variety used Revolution.*

It can appreciated from Table 16 that losses are minimum for a warehouse refrigerated at 4°C. Losses are higher for field pile covered with potato and ground, while in the other types few differences are had in five storage months.

For short storage period (1 month) adobe warehouse with natural ventilation is almost so efficient as one refrigerated.

For a half storage period (3 months), losses in adobe warehouse are clearly higher to those of refrigerated warehouse, but they are smaller to those of the other types.

For long storage period (5 months), there is a marked difference among losses in warehouse refrigerated and the rest that tend to be equalled, to exception of one mentioned before covered with straw and ground which is clearly higher.

3. Overall Losses

Total losses are all reductions suffered during pre-harvest, harvest, sorting and pre-processing, packing, transport, storage, processing, handling and distribution.

Table 17 describes systems components for post-harvest losses observed in Costa Rica that according to this data fluctuate between 18. 51 percent for perishable products. Fresh potato is included in these statistics.

Table 17. System components post-harvest losses in Costa Rica (losses % for each component)

System Component	Losses
Pre-harvest factors	3-8%
Sorting and pre-processing	2-5%
Packing	1-2%
Transport	3-6%
Storage	1-4%
Processing	4-8%
Handling	1-5%
Urban distribution	2-8%

Source: Alvaro Jara Solís, *1991*

Table 18 indicates percentages of potato waste in developing countries. Asia stands out with 15 percent losses, followed by Latin America and the Caribbean with potato losses of 11 percent.
In Table 19 total loss estimates are presented for some countries. United States registers the smallest loss at 13 percent and Dominican Republic the largest with 27 percent. It is important to note that loss averages fluctuate between 25 and 27 percent.
In case of Peru, no total losses for potato are quantified, but according to officials of the Peruvian Ministry of Agriculture losses in an improved storage facility can be 15 percent. This contrasts to up to 50 percent in a traditional warehouse over a 6 month storage period.
Wholesale Market N°1 in Lima, Peru reports from 1 000 to 1 200 TM/day potatoes incoming, which is supplied with potatoes coming from the Andean uplands (Sierra) (95 percent) and coastal desert plains (Costa) (5 percent).

Table 18. Potato waste percentage in developing countries.
Averages in 1991-1992 years.

COUNTRY and REGION	% WASTE
ASIA	
Bangladesh	15
China	10
India	5
Indonesia	17
Iran	6
Korea RPD	10
Nepal	10
Pakistan	15
Syria	10
Turkey	13
Vietnam	11
AFRICA	5
Algeria	10
Egypt	10
Madagascar	11
Malawi	12
Morocco	10
Rwanda	11
LATIN	4
AMERICA and	11
CARIBBEAN	10
Argentina	8
Bolivia	8
Brazil	5
Chile	12
Colombia	10
Cuba	13
Ecuador	9
Mexico	10
Peru	

Source: CIP. FAO, 1995.

In Table 20 total losses estimate in Wholesale Market N°1 in Lima, the most important market in Peru is shown. The main loss at 27.2 percent is caused by rottenness. This occurs when potatoes are received with insects, mechanical damages, and microbial contamination. Secondary cause is greening at a rate of 22.4 percent because the potato sacks are exposed to sunlight. Thirdly, crop weight loss represents 13.8 percent due to lack of refrigeration for stored potato tubers. Because bulk potatoes are marketed in Lima, studies have evaluated daily and annual wastes, plus their economic value. In Table 21, an appraisal of potato wastes for Wholesale Market N° 1 in Lima is shown.

It is estimated that daily potato wastes is of 28 645 kg, is equivalent to S/. 22 000 new soles in monetary terms. Annually wastes totalled 10 402.5 TM, or S/. 8 322, 000 of new soles.

Table 19. Total Losses Estimate in Fresh Potato percentage in Some Countries

COUNTRY	%
Peru	n.a.
Colombia[1]	25
Rep. Dominicana[1]	27
Ecuador[2]	7-20
United States[4]	13
Costa Rica[4]	24.36

Sources: 1. Mendoza Gilberto, 1994 2. Valderrama Mario, 1977 y IICA. PROCIANDINO, 1990 3. Van Norel Pauling, 1993 4. Jara Solis Alvano, 1991. n.a.: not available

Table 20. Total Waste Estimation in Wholesale Market No. 1 in Lima

Waste Causes	%
Rottenness	27.2
Weight loss	13.8
Contusions	10.5
Greening	22.4
Wrong sorting	5.6
On retailer sale	3.1
Steal	5.8
Excessive duration on market	11.6%
TOTAL	100%

Source: Brandes Salazar; Dazzy *et al*, 1997.

Table 21. Waste Economic Value in Wholesale Market N°1 in Lima

Potato daily wastes:	28 465 kg
Potato mean value in 1996:	0.8 soles/kg
Waste loss mean value:	22 800 soles
Potato annual losses:	10 402.5 TM
Waste loss annual mean value:	8 322 000 soles.

Source: Salazar Brandes, Dazzy *et al*, 1997.

Table 22 presents total potato loss according to a survey carried out to 28 producers in theNorth area of Cartago in Costa Rica. From these data it is ascertained that plagues (pests) represents 12.67 percent of loss, following by small potato at 6.32 percent and illness at 3.87 percent. It is necessary to recognize that countries of Latin America and the Caribbean experience similar problems. A critical eye must be directed to these plagues to diminish total losses.

Table 22. Total Potato Loss According to a Survey of 28 Producers in North Area Cartago County in September 1990-Costa Rica

CAUSE					
LOSS	**SICKNESS**	**PLAGUE**	**MECHANICAL DAMAGE**	**SMALL POTATO**	**TOTAL**
(%)	3.89	12.67	1.49	6.32	24.36

Source: Jara Solis, Alvaro, 1991.

4. Pest Control

Post-harvest losses quantitative as well as qualitative, are often due to physical, physiologic and/or biological causes.

Storage is only a part of total production system. Production factors before harvest exist that influence tuber behaviour in storage.

Losses due to biological factors (pathologies and invasions) are usually the most important. Fungi, bacteria, virus, insects and rodents cause them. With exception rodent attack that is typically in storage, it is difficult to distinguish when damage corresponds to pre-harvest or post-harvest. In general, tubers arrive polluted from field. If the initial infection has passed unnoticed and storage conditions favour development of infectious organisms, plagues or diseases are manifested during storage period.

Infection cycle is completed when potatoes stored as seed are infected and remain in latency state at warehouse. When these tuber seeds return to ground there is an appropriate environment for insect development or pathogenic microorganisms.
Potatoes taken to the warehouse should be healthy, dry and clean, without ground. It should be protected from rain and sun exposition and wind.
Special care should be had in sanitary aspects and tools, machinery deposits and warehouses cleaning, with purpose of preventing insect invasion sources or inoculation of potential pathogens.

4.1 Pest species

Among insect pests that attack potato, the most important is potato tuber moth (PTM). Others also present a hazard to tubers:
Cutzo (*Barotheus sp.*)
Leaf bug (*Proba sallei*)
White worm (*Preomntrypes sp.*)
Leaf worm (*Copitarsia sp.*)
Cut worm (*Agrotis ypsilon*)
Potato tuber moth (PTM) (*Pthorimea operculella*)
Green peach aphid (*Myzus persicae*, *Macrosiphum euphoria*)
Potato flea beetle (*Epitrix sp.*)
Thrips (*Frankliniella sp.*)

4.1.1 Potato Tuber Moth (PTM) *(Pthorimea operculella)*

In larvae state *Pthorimea operculella* damages foliage mining between the inferior epidermis and superior of the leaves. It is also introduced in the tuber mining burrows and filling them with their excrements. The initial invasion happens in the field and continues in storage.
Damage to potato crop can be keep to a minimum with an integrated approach that combines cultural and physical methods (earthing up, irrigation, sorting, sanitation, etc.), chemical (insecticides) and biological (natural parasites, synthetic pheromones, etc.)
Virus
The main diseases caused by virus are the following**:**
PLRV - Potato leafroll
PVY - Rugose mosaic, severe mosaic
PVX - Potato mild mosaic, rugose mosaic, severe mosaic
PYVV- Potato yellow vein virus
For their control, healthy seed should be used, sick plants should be eliminated at field and vectors should be controlled (tools, insects, etc.)
Fungus diseases
Among the diseases of fungi origin, the most important are the blight or late blight and the dry rot.
Black spot or early blight (*Alternaria solani*)
Pink rot (*Phytophtora erythroseptica*)
Fusarium dry rot (*Fusarium sp.*)
Black spot or late blight (*Phytophtora infestans*)
Rhizoctonia canker (*Rizoctonia sp.)*
Scab or powdery scab (*Spongospora subterranea*)
Common rust (*Puccinia pittieriana*)
Deforming rust (Peruvian rust) (*Aecidium cantensis*)
Wart (*Sinchytrium endobioticum*)

<u>Fusarium Dry Rot</u> (*Fusarium sp.*)
The symptoms of the disease become evident after a storage time. The skin wrinkles forming irregular concentric rings, and in general tuber tissue decay forms pocks of pink, red or colour or bluish colour, which contain spore masses in the mycelium.
It can control disease incidence with a curing appropriate and opportune. Tuber bruising should be avoided during harvest and transport.

<u>Black Spot or Late Blight</u> (*Phytophtora infestans*)
It reduces yield by premature foliage death and tuber rot, as much in the field as in the warehouse. The infected tubers exhibit some of brown or purple coloured spots that spread toward the interior forming in the pulp some necrotic lesions. When the storage conditions are good, the rot remains dry and doesn't extend. However, when the storage conditions are faulty, the dead tissues open a route to the secondary soft rot.
Sanitation is important to reduce the first inoculum sources (infected seed, waste mounds, etc.). Organic fungicides and those made in base of minerals are useful when are used as protection sprayings. Good cultivation practices (appropriate earthing up, residues elimination, selection and destruction of invaded tubers, etc.).

<u>Bacterial diseases</u>
Among the main diseases of bacterial origin we have:
Bacterial wilt (*Pseudomonas solanacearum*)
Blackleg or blackpaw and soft rot (*Erwinia carotovora var. carotovora* and *Erwinia carotovora var. atroséptica*)
Ring rot (*Corynebacterium sepedonicum*)
Common scab (*Streptomyces scabies*)

<u>Blackleg or Blackpaw and Soft Rot</u> (*Erwinia carotovora var. carotovora* and *Erwinia carotovora var. atroseptica*)
The symptoms of blackleg or blackpaw are leafroll apical and yellowing of leaves that it culminates in wilt and death. The stems base tissue is turned necrotic. In storage, the infected tubers present watery rot and unpleasant odour, due to the presence of other bacteria.
Soft rot is one of the most frequent causes of losses in storage. It can be developed by infections of lenticels, wounds superficial, crackings, contusions, etc. is also occurs as secondary disease, after damage caused by insects. These bacteria are supported in storage by high temperatures and humidity plus anaerobic conditions.
For effective control of this disease, healthy seed should be sowed to achieve good ground preparation, appropriate drainage, eliminate sick plants and make good tuber selection before storage.
Soft rot can be avoided in storage by placing the tubers in a cold and dry environment. The development of anaerobic conditions should be avoided.

<u>Ring Rot</u> (*Corynebacterium sepedonicum*)
This disease causes the atrophy of one or more plant stems. It originates in the seed. The affected tubers show a ring of brown colour that fades and rots to give access to microorganisms that cause the secondary soft rot.
The bacteria don't survive on the ground, but in tools, sacks and deposits. Control is carried out using healthy seed and strict practices of sanitation.

<u>Nematodes</u>
Among the nematodes that affect potato crop are:
Nacobbus aberrans
Globodera sp.
Meloidogyne sp.

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6. Annex

6.1 List of Tables

6.2 List of Figures

6.3 List of Diagrams