

THE NUTRITIVE VALUE OF POTATOES AND ITS PRODUCTS

By

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Introduction

Potatoes are thought to have originated in the Andean highlands of South America and for thousands of years they have been used to maintain and support the growth and health of large number of humans. The introduction of the potato was initially a great blessing since it provided the peasants with a cheap alternative crop to cereals. Until the eighteenth century the history of all the European countries was marked by famines due to failure of the main cereal crops as a result of drought or disease. Potato cultivations provided a second crop which allowed a population to survive despite a failure of the cereal harvests. The dependence of the Irish and Scots on potatoes as their principal source of nourishment and the resulting famine of 1846-47, when their potato crop failed due to blight, are well documented (Salaman, 1949; Woodham-Smith, 1962). Furer-Haimendorf (1964) has argued that the introduction of the potato into the Sherpa Kabumbu region of Nepal stimulated population growth and provided the agricultural surplus necessary for the rise of the elaborate Buddish Civilisation in the northern part of the country.

Nutritive Value

The potato has two remarkable properties. First it is the cheapest food that can best support life when fed as the sole source of diet. Secondly, potatoes yield more energy per acre than any cereal crop. The potato has been shown to be a source of good quality protein, to have a favourable ratio of protein calories to total calories and to be an important source of vitamins and minerals. Yet its overall value in the diet nowadays is generally under-estimated.

One practical goal of food and nutrition policy planners in developing countries is to reduce disparities between requirements and intakes of nutrients. Comparison of the nutrient contents of various food crops indicates which food may be of particular value in improving local diets and therefore should have increased. The potato is a staple food in those tropical regions where elevation provides a moderate cool season climate. In other tropical countries it is used as a vegetable. The chemical composition of potatoes and some other plant foods is shown in Table-1.

The potato has a lower average carbohydrate content than do other roots and tubers and also a comparable fat content. Raw potatoes have a somewhat lower energy content than other raw roots and tubers. The energy content of raw potatoes is considerably less than that of raw cereals and

legumes; however, when cooked, the latter staples absorb large quantities of water, which changes their composition significantly. The potato when boiled in its skin, retains its energy value almost unaltered. A fairer comparison of the potato and the cereal or legumes, therefore, is either on a dry, raw basis or on a cooked, as eaten basis.

Starch furnishes most of the energy supplied by the potato. The digestibility of potato starch, low in the raw state, is generally improved during cooking and processing, but there is some doubt about the extent of digestibility of cooked potato starch in infants and small children.

Potato Protein

Table 2 shows the essential amino acid content of potato in comparison with some other plant foods. The potato proteins like other vegetable proteins are deficient in sulfur containing amino acids, cystine and methionine. Their content of sulfur containing amino acids (2.9 g/16 g N) is lower than that of rice and wheat (3.7-4.0 g/16 g N) however they contain more of these essential amino acids when compared to phaseolus beans (1.9 g/16 g N). The potato has advantage over cereals in its high lysine content (Laung et.al, 1972). Phaseolus beans also contain greater quantities of lysine. In combination with other foods, potatoes can supplement diets which are limiting in lysine e.g rice and wheat with accompanying potatoes provides a better quality protein. In some developing countries, meals are frequently served with mixtures of boiled potato and rice and/or pasta. Such mixtures are often wrongly assumed to provide nothing more than large quantities of energy.

The comparative advantage of potato as a food stuff in the tropics, on a unit weight basis, lies in its ability to supply high quality protein (Werge, 1979). Using the latest figures for energy and protein requirements (WHO, 1985), it can be calculated that 100 g (one small tuber) of potato can supply 7%, 6% and 5% of the daily energy and 12%, 11% and 10% of the daily protein needs of children 1-2, 2-3 and 3-5 years respectively. For adults, depending upon body weight and sex, 100 g of potato can supply 3-6% of daily requirements.

For infants and children, an energetically adequate diet cannot support growth if its protein content is inferior to its requirements. Conversely, with an energetically inadequate diet, protein is metabolized as an energy source, instead of being used for growth. It is therefore essential to consider the quality of a food or diet in terms of both protein and energy. A useful estimate of protein quality and quantity is the net dietary protein calories percent (NDpCal %). The NDpCal% of breast milk is 7.6 which meets the known requirements of infants. As children grow, energy requirements increase and percentage drawn from protein decreases until, at one year age, the children require an NDpCal % of about 6. Table 3 shows the NDpCal % of some staple foods and indicates that potato and some cereals have approximately the correct balance between net protein calories and total calories for the end of the first year of life and are also adequate for children 4-9 years and adults. However they are inadequate to meet the needs of toddlers, adolescents male, females and lactating mothers.

Potato Fibre

In recent years there has been increasing interest in dietary fibre as a result of suggestions that it gives protection against diverticulosis, cardiovascular disease, colonic cancer and diabetes. Recent methods show that the quantity of dietary fibre in foods including potatoes, is higher than that of crude fibre. Crude fibre analysis have been largely abandoned as they measure only a small and variable fraction of dietary fibre. Part of the dietary fibre may be starch that is resistant to hydrolysis by the enzymes used to remove starch prior to dietary fibre determination. This resistant starch may be produced by subjecting foods to heat and/or dehydration, which confers a more ordered structure on the starch molecules and renders them less susceptible to enzymic digestion.

It has been shown that various types of dietary fibre have differing physiological effects. For example, insoluble cereal fibre affects transit time and faecal weight, whereas soluble gel-forming fibre has been shown to reduce serum cholesterol levels and blood glucose and insulin response to meals containing carbohydrates. A chemical characterization of the dietary fibre in various foods (Theander, 1983) revealed that cereal brans have the highest lignin values, are rich in arabinoxylans and cellulose, but are low in uronic acid, whereas various vegetables, including potatoes, have higher cellulose, but are low in uronic acid, whereas various vegetables, including potatoes, have higher cellulose contents and more pectic and pectin - associated substances than brans.

The fresh potato has a dietary fibre content similar to that of sweet potato but somewhat lower than that of other roots and tubers and much lower than that of most cereal and dry phaseolus beans, although on a dry basis, potatoes and cereals are similar in this respect. Potatoes cooked as french fries or chips are a more concentrated source of dietary fibre. Thus 100 g of boiled potato supply 1.0, 0.7 and 0.5 times the fibre that can be found in a 35 g medium slice of white, brown or wholemeal bread, respectively; a 25 g packet of chips supplies 1.9, 1.4 and 1.0 times the respective bread fibre contents. There is no recommended allowance for dietary fibre at present. It has been suggested that 30-40 g/day should be consumed to maintain correct colonic function. Consumption of the whole tuber, rather than the flesh alone, may increase dietary fibre intake.

Vitamins

Potato is an excellent source of some of the water soluble vitamins. The thiamine content depends upon variety (Swaminathan and Pushkarnath, 1962) and location (Leischsenring et. al 1951). Tubers from loamy soil contained more thiamine than those from sandy soils and thiamin content is greatly increased by nitrogen fixation (Augustin, 1975). A large difference in ribo-flavin content but small difference in niacin content has been found amongst varieties (Swaminathan and Pushkarnath, 1962). Riboflavin was unaffected by soil type and little affected by nitrogen fixation when potatoes were grown on little affected by nitrogen fixation when potatoes were grown on sandy soils, but was increased somewhat by

nitrogen fixation on loamy soils. Niacin was unaffected by soil type, but was increased by nitrogen fixation on both sandy and loamy soils (Augustin, 1975). Reduced ascorbic acid content of potatoes varies with variety, locality, crop year and maturity at the time of harvest (Leischenring, 1951). The amount of difference between varieties is dependent upon the variety under consideration and vitamin C were highest when the plants were at their maximum vigour and declined thereafter as vines began to die off. Recent studies (Augustin, 1975) have confirmed these findings and showed an additional dependency on soil type and nitrogen and phosphorus fertilization.

Minerals and Trace Elements

The ash content of potatoes is about 1% and contains some important minerals and trace elements. Mineral contents have been reported to vary with soil type, location of growth and application of phosphorus (True et al, 1978). Varietal differences have also been noted in the contents of calcium, phosphorus and iron in 13 varieties grown at the same location (Leishenring et al, 1951). A more recent study also found varietal variation in iron and copper levels (Kubisk et al, 1978). Content of calcium, phosphorus and iron were also influenced by location and this was more important in case of calcium (Leischenring et al, 1951). Wide ranges in calcium, phosphorus, sodium, potassium, selenium and aluminium observed in 9 varieties grown at 5 locations were attributed to location of growth rather than to variety (True et al, 1978). Nitrogen fertilization had little effect on magnesium, calcium, potassium, sodium and phosphorus levels (Augustin, 1975). However, iron content was increased somewhat, and the tuber grown on sandy soils had lower quantities of magnesium than those grown on loamy soils. In potato, the percentage of total phytic acid is much lower than in the cereals and thus has little effect on the availability of minerals such as iron, zinc and calcium. Potatoes can supply a high percentage of iodine requirements (depending upon the iodine content of the soil), smaller percentage of zinc requirements and can make some contribution to supplies of copper, manganese, molybdenum and chromium.

Potatoes are rarely eaten alone. Their importance in this respect depends upon the area of the world and the particular meal under consideration. In some parts of Peruvian Sierra, a meal may consist entirely of potatoes. In Pakistan and India they form part of many vegetable and meat dishes. Potatoes are also eaten as a snack food in some parts of the world. In main meals or snacks they can provide at least part of the body's requirements for many essential nutrients.

Effect of Storage, Cooking and Processing:

Storage

Good storage should maintain tubers in their most edible and marketable condition by preventing large moisture losses, spoilage by pathogens, attack by insects and animals and sprout growth. It should also prevent large accumulation of sugars, which leads to an unpleasant sweet

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taste, and particularly in fried processing products, to a dark coloration. Prevention of tuber greening and glycoalkaloid accumulation is also important. At harvest, tubers are dormant, the dormancy period varied in length depending mainly upon the variety of potato and storage temperature. During dormancy and sprouting, further changes in nutrient content take place which affect the nutritional value of stored potatoes; these changes are less pronounced during dormancy, so storage conditions should aim to prolong the period and delay sprouting.

Normally, over a range of 4-21°C, the lower the storage temperature, the longer the dormant period. Sprout growth is slow at temperature upto 5°C and below. Above 5°C increasing temperature causes increased sprout growth upto about 20°C, at higher temperature the growth rate decreases. However, lowering the temperature to below 10°C causes an increase in sugar content which becomes marked below 6°C. This decreases the culinary acceptability of tubers and increases the brown coloration of heat processed products which occurs as a result of reactions between aminoacids and reducing sugars. Tubers affected by low temperature sweetening can be reconditioned (i.e. desweetened) by being held for about 2 weeks at 15-20°C. However, sugar may accumulate after prolonged storage at higher temperatures. This is called senescent sweetening and is irreversible.

Methods of storage vary from delayed harvesting, or storage in simple piles or 'clamp', to storage in buildings specially designed for the purpose with controlled temperature and humidity. Before storage, tubers are generally allowed a period of about 2 weeks at 10-15°C to undergo wound healing. During storage, tubers may lose moisture as a result of evaporation. Such losses will be minimum if the relative humidity of the store is controlled.

a) Nitrogenous constituents

On the whole changes in total N are small. Weaver et. al (1978) however reported a decrease of 8% in total N after 4 months of storage at 5°C, while storage at the same temperature for only two months had no effect on total N. Toma et.al (1978) showed a small increase in total N during 8 months of cold storage, but this change was not significant in all the varieties studied. Talley et.al (1984) held two varieties for four months at 3°C or 7°C and found that N increased significantly at lower temperature but not at the higher one. However, no differences in total N were found by Fernandez and Aquirre (1965) between tubers stored for five months at 20°C or those in cold storage at 3°C, nor was there any difference between these and the tubers stored at 20°C and treated with chemicals or irradiation to prevent sprouting. Some evidence indicates that protein breakdown may occur as a result of sprouting. Klein et al (1982) observed a decrease in the ratio protein N:NPN in the cortex of three varieties and in the pith of two of these when potatoes sprouted. However, although sprouts contained much higher levels of nitrogenous constituents than the tuber tissues, there were no significant reductions in these constituents in the tuber. Changes in individual total aminoacids have been studied in two varieties for a period of 4 months storage at 3°C or 7°C (Talley et al, 1984). Changes were either small or insignificant. Lysine, tryptophan, aspartic acid and arginine increased at both

temperatures. Threonine, valine, leucine, phenylalanine and histidine increased only at 30°C, whereas cystine increased only at 7°C.

b) Fibre

Little variation occurred in crude fibre levels in several North American varieties stored at 3.3°C for upto eight months (Toma et. al, 1978).

c) Ascorbic acid

Various authors have investigated the extent of ascorbic acid loss during cold storage and found decreases of 40-60% over the course of several months (Sweeney et.al, 1969; Augustin et.al, 1978; Faulks et.al, 1982). Wills et.al (1984) found no dehydroascorbic acid was in the dehydroascorbic acid in fresh potatoes, but after six weeks of storage, 36% of total ascorbic acid was in the dehydro form. Losses have been found to occur most rapidly during the early part of storage. One-third to one-half of total loss over seven months of storage occurred during the first month (Murphy, 1946). The sharpest decrease in total ascorbic acid content occurred during the first 3-4 months of storage at 7°C (Augustin et.al, 1978), at 12°C (Mareschi et.al, 1983) or at an unspecified temperature (Finglas and Faulks, 1984), followed by a levelling out or less pronounced decrease during the following months, depending on variety.

Furthermore, at any storage temperature, initial differences in tuber ascorbic acid levels are reduced, so that at the end of storage there may be comparatively little differences in ascorbic acid contents. Augustin et.al (1978) found that after 8 months of storage, total ascorbic acid values were similar whether they had been initially high or low immediately after harvest. Moreover, they were close to the final total value of 'White Rose' potatoes stored for 30 weeks (Yamaguchi et.al, 1960). Storage temperature may also influence the final content of ascorbic acid. Murphy (1946) found that the optimum temperature for maximum retention of reduced ascorbic acid and maintenance of good physical quality is 10°C over a period of 7 months of storage, although at 15, 18 and 21°C, more vitamin C was retained than at 0 or 2°C. Of the three storage temperature studied by Effmert et.al (1961) smallest decrease in reduced ascorbic acid during seven months of storage of 20 varieties was at 15°C, followed by 1°C and then 5°C.

Linnemann et.al (1985) studied the effects of high storage temperatures on the reduced ascorbic acid content of 'Binje' potatoes in an attempt to simulate conditions in developing countries. Tubers were stored at 16°C or at 28°C and at 55-60% relative humidity for 12 weeks. At the end of this period the 16°C tubers had a few small sprouts, whereas the 28°C tubers were soft, shrivelled and had long, thick sprouts. The initial ascorbic acid content of 8.2 mg/100 g had increased to 10.1 and 10.5 mg/100 g in the 16 and 28°C stored tubers respectively. These findings indicate that vitamin C losses from potatoes in developing countries are likely to be lower than those during low temperature storage.

d) B-Complex vitamins

Reports of changes in thiamin content during storage are variable; in general, changes appear to be small and rather erratic. Only Meiklejohn (1943) found a large loss in thiamin during storage, but attributed this to sprouting rather than storage per se, as the sprouts had a higher thiamin content than the tubers from which they had grown. After 6-7 months of storage about 30-50% of the vitamin was lost from the tuber by translocation to the sprouts. At temperatures of 5°C or 10°C, Yamaguchi (1960) found no significant changes in thiamin in 'White Rose' potatoes even after 30 weeks of storage. A small but significant increase in thiamin was found after 8 months of storage of two varieties stored at 3°C and in most of the samples of 6 varieties stored at 7°C (Augustin et al, 1978). The overall change in niacin was not significant for 30 weeks of storage at 5°C or at 10°C in 'White Rose' potatoes (Yamaguchi et al, 1960). A general decrease in niacin values after 8 months of cold storage at 7°C has been reported (Augustin et al 1978). Increase in pyridoxine during storage have been demonstrated. There was a continuous increase in pyridoxine in both 'Cobbler' and 'Triumph' varieties from harvest time to the end of a six month storage period at 4.5°C (page and Hanning, 1963). The total increases were 152% and 86% respectively for the two varieties. Augustin et al (1978) also found significant increases in pyridoxine during storage e.g. in variety 'Katahdin' it increased by 126% at the end of 8 months at 7°C. It is not known if this increase is due to synthesis of the vitamin or its release from a bound form during the early stages of storage. In contrast to pyridoxine, total folic acid decreased in all six varieties analysed over the 8 month cold storage period and losses ranged from 17-40%. The losses were most rapid during the first four months and thereafter showed little change upto eight months.

Minerals

The limited information available indicates that changes in mineral constituents during storage are insignificant. In general there was no change in the total ash content of two varieties at 3°C or of six varieties at 7°C over a period of 4-8 months of storage (Toma et al, 1978). Losses of minerals on cooking after 24 weeks of storage at 6°C were not greater than those after only two weeks of storage. Mica (1979) found for 10 cultivars that although phosphorus contents tended to increase and potassium decreased during storage and boiling, these changes were not significant. Yamaguchi et al (1960) observed no significant changes in the contents of calcium, iron or phosphorus in 'White Rose' potatoes held at 5°C or 10°C for 30 weeks.

Domestic Preparation

The method of peeling can greatly affect the quantity of loss. Scrapping young potatoes removed about 5% of weight as waste, while peeling increases this to 20-24% (Szkiladziowa et al, 1977). The nutrient content of peel as a percentage of that of whole tuber is shown in Table-4. The tuber centre has been suggested to be the site of highest concentration of thiamin, peeling therefore should not result in

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significant losses of thiamine. The outer parts of the potato contain mainly insoluble protein of negligible nutritional value and removal of the skin by careful peeling does not adversely affect the protein quality of potato. Rats given diets containing steamed, peeled potato as the sole source of N grew better than those on a diet with steamed, whole potato (Chick and Slack, 1949). The effect of cooking on the chemical composition of potatoes and some other plant foods is shown in Table-5.

Experimental work shows without exception that the boiling of potatoes in their skin is nutritionally superior to peeling the potatoes before boiling. It is noteworthy that potatoes are usually boiled intact by consumers in many developing countries in contrast to the practice of peeling tubers before cooking in e.g. USA and UK. Cutting tubers exposes a greater surface area to the water and increases losses of nutrients by blanching.

The major part of potato carbohydrate is present as starch. Raw potato starch when fed to humans causes symptoms such as violent cramps (McCay et.al, 1975) and Caecal hypertrophy and death in rats (El-Harith et.al, 1976). The latter effects were subsequently attributed to the resistance of potato starch to digestion by pancreatic amylase (Walker and El-Harith, 1978) and were lost when the starch was gelatinized. Cooking either peeled or unpeeled potatoes increases the digestibility of potato starch. Potatoes judged to be adequately cooked for 25 to 30 minutes have lower digestibility than those overcooked for 40 min. Englyst et.al (1982, 1987) and Jones et.al (1985) found varying quantities of starch that is resistant to enzymic hydrolysis *in vitro*, in samples of cooked potato.

In general, negligible or small changes in the content of nitrogenous constituents take place when potatoes are boiled whole, unpeeled (Toma et.al 1978, Talley et.al, 1983). This rose to 4% when unpeeled potatoes were halved or quartered and was highest in boiled, peeled potatoes - 6.5% in the whole tuber and 10% in halved or quartered tubers and aspartic and glutamic acid predominated in the boiled water fraction. When potatoes are peeled and/or cut and stored sometime before cooking, they readily undergo enzymic browning, involving chlorogenic acid or amino acids. Substantial losses of sulfur aminoacids take place during this browning. Avoidance of this loss is achieved easily by cooking peeled potatoes immediately or immersing the tuber in water.

Smallest losses of ascorbic acid occur when unpeeled potatoes are boiled or steamed. Whole, boiled, unpeeled potatoes retained 80% of their reduced ascorbic acid, whereas boiled, peeled tubers retained only 74% (Augustin et.al, 1970) Thiamin may be little affected by boiling. Augustin et.al, 1978) reported in niacin content of 100% for boiled unpeeled, and of 92% and 80% respectively, for peeled, whole or peeled, quartered, boiled potatoes. Pyridoxine is unaffected when potatoes are boiled in their skin. There was 85% retention of pyridoxine when peeled potatoes were boiled. Riboflavin content was found to be unaltered in potatoes boiled in their skin and only slightly lower in boiled peeled, cut potatoes. In comparison, the overall riboflavin retention was 87% in whole, unpeeled and only 75% in whole, peeled, boiled tubers.

Research providing information on changes in mineral constituents during boiling and peeling resulted in a loss of 18% total ash in four varieties (Toma et.al., 1978), while there was no difference in the ash content of raw and unpeeled, boiled potatoes.

Methods of domestic preparation of potatoes, other than boiling, may require one or more stages to achieve the end results and the losses of nutrients are therefore comparatively greater. No differences were found in the content of total N of any of the three Indian varieties either deep fat fried from raw or baked (Roy Choudhri et.al., 1963). There was however a significant difference in N content of two of four North America varieties when boiled, steamed or pressure-cooked (Leischenring et.al., 1951). A loss of 24-68% was found when the cooked potatoes were mashed and 58% when the mashed potatoes were warm-held on a steam table for 45 min. such destruction is largely due to oxidation. Thiamin is fairly stable during the domestic preparation of potatoes. Baked potatoes retain 86% of their thiamin, a retention similar to that of boiled tubers. Niacin, being heat stable, is mainly lost by leaching in cooking water, especially when tubers are peeled or cut before boiling. The overall retention of niacin in baked potatoes has been found to be 91%, while the retention of riboflavin was 77%. Riboflavin was partially destroyed (20-65%) when the potatoes were fried, depending upon whether they were unpeeled, peeled, cut, boiled and then fried. The mean retention of folic acid in baked potato was 71% (Augustin et.al., 1978).

The total ash content is unaffected by holding, mashing or hashbrowning potatoes previously cooked whole, unpeeled or by overbaking (Toma et.al., 1978). Sodium, potassium, calcium, magnesium, phosphorus, iron, zinc, iodine, boron, copper, manganese, molybdenum were virtually unaffected by baking in three North American varieties (True et.al., 1979), except in case of 'Norchip' which showed unaccountable low retention of calcium, copper and iron.

Industrial Processing

Peeling

The vitamin losses as a result of different methods of peeling are presented in Table 6. Peeling by steam retains the greatest quantities of vitamins. However even these losses are substantial for thiamin and riboflavin.

Sulphiting

Pre-peeled potatoes are immersed in a solution usually of sodium metabisulphite for a few minutes to inhibit discoloration by enzymic browning. As sulfite is a reducing agent vitamin C losses are minimum and these are due to leaching of the vitamin into solution. Thiamin is converted by sulfite into inactive thiazole and pyrimidine sulfonic acid and losses are considerable depending upon the surface area exposed to sulfite, the concentration of solution the quantity of sulfite absorbed and length of subsequent storage time. After sulfite dipping and 8 days of

storage at 30°C, whole and french-fried potatoes had lost 11% and 47% respectively of their thiamin content.

Frozen Potato Products

Since 1970, frozen potato products have accounted for 45-48% of all potatoes used for processing in USA or nearly one quarter of its food use of potatoes. Frozen french fries or frozen chips are the most important frozen potato product. Commercial brands contain only about 66% of the protein of the home prepared product. The losses occur during blanching and through Maillard browning during frying. Vitamin losses can be considerable. The processes responsible are peeling and slicing. The frying itself causes negligible vitamin losses. Overall losses in the finished product made from freshly harvested potatoes were 44% ascorbic acid, 44% thiamin, 32% riboflavin and 24% niacin (Gorun, 1978). These increased to 72%, 52%, 45% and 35% respectively, when the potatoes were stored for 6 months prior to use. Potato patties, puffs and rounds, hash browns and mashed potato are other frozen products. Information is scant on nutrient losses except for potato patties (Augustin, 1979). Retentions for total N (90%), pyridoxine (91%) and folic acid (73%) respectively were found in commercial patties. The approximate losses of vitamins during domestic preparation and commercial processing of potatoes are presented in Table 7 and 8 respectively.

Studies of the effect of chipping show considerable damage to protein with free amino acid loss of 50-60% and reducing sugar loss of 70%. Losses of all amino acids were great (100% of methionine) in stored fried chips. Vitamin C losses are 30-85%. However, in spite of substantial losses of nutrients, potato chips are still quite a good source of these nutrients, as a considerable concentration effect is achieved through the reduction of moisture content (Pelletier et al., 1977).

Dehydrated Products

Dehydration is one of the major means of preserving potatoes yielding products such as potato flour, granules, flakes and dice. The dehydration industry is particularly important in France, using 61% of all potatoes destined for processing. Potato flour can be incorporated into bread and is used as a combination thickener - flavouring agent in products such as dehydrated soups, gravies, sauces and baby foods. Potato granules and flakes are convenience foods for both domestic and large scale use. The granules and flake process can use potatoes rejected by other sectors, as they are less sensitive to raw material requirements. Dehydrated potato dice are ingredients in processed foods such as canned meat, meat stews, frozen meat pies and potato salad. The chemical composition of processed forms of potatoes is shown in Table 9.

During preparation of dehydrated products, there are physical losses due to peeling and leaching and chemical losses as a result of amino acid-sugar interactions at the elevated temperatures required for drying. During processing, water blanching greatly affected total N in granules, flakes, slices and dices (Augustin et al., 1979). Dehydration had little

effect on nitrogen content in the case of granules, slices and dices but considerably reduced it in the case of flakes. The overall retention was for granules (83%), flakes (70%), slices (85%) and dices (86%).

Thus thiamin values have been severely reduced in the case of granules, slices and dices during processing while other vitamins are lost to a lesser extent. The chemical composition of some commercial potato products used in Pakistan is presented in Table 10. The protein content ranges from 4.8-7.0%. The fat content is quite high (42.0-47.0%) except in case of Bingo (18.0%). Thus all the above potato products except Bingo are rich in energy content.

Canned Potatoes

Canned food is convenient but is more bulky and expensive to transport than dehydrated products. In terms of total processed potato products, the canning sector plays a minor role. The total N of canned potatoes was less than that of raw potatoes but the lost N (about 22%) was found to be present in the brine as a result of leaching during processing. Ascorbic acid and thiamin are also partially lost into the surrounding liquid. As content of canned potatoes was slightly higher probably due to absorption of sodium chloride from the surrounding brine. No difference was noted in iron and phosphorus content but calcium content was slightly higher probably due to soaking of potatoes in calcium chloride followed by washing before blanching, filling and canning (Roy choudhry et.al., 1963).

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Table 1

Chemical composition of potatoes and other plant foods
(per 100 g edible portion)

Food	Moisture (%)	Energy (Kcal)	Protein (g)	Fat (g)	Total Carbohydrate (g)	Crude Fibre (g)	Ash (g)	Ca (mg)	P (mg)	Fe (mg)	B Equivalent (ug)	Thiamine (mg)	Ribio-Flavin (mg)	Niac-in (mg)	Ascorbi-Acid (mg)
Potatoes	78.0	80	2.1	0.1	18.5	2.1	1.0	9	50	0.8	0-trace	0.1	0.04	1.5	20
Potatoes(dried)	11.7	321	8.4	0.4	74.3	8.4	4.0	36	201	3.2	trace	0.4	0.16	6.0	80
Sweet Potato	64.5	116	1.4	0.4	27.4	2.5	0.8	33	46	1.1	47-2108	0.11	0.05	0.7	26
Yam	71.8	106	2.2	0.2	24.2	4.1	1.0	25	53	0.9	0.10	0.1	0.03	0.5	9
Corn mature	63.5	129	4.1	1.3	30.3	1.0	0.8	5	128	1.1	35	0.18	0.08	1.9	9
Rice, milled white	120	364	6.8	0.5	80.2	2.4	0.6	20	115	1.1	0	0.08	0.04	1.8	0
Wheat, hard	12.3	332	13.3	2.0	70.9	12.1	1.7	44	359	3.9	0	0.52	0.12	4.4	0
Beans dry	11.8	338	21.9	1.6	61.2	25.4	3.7	98	247	7.6	0.20	0.53	0.19	2.2	0-3

Source: Paul and Southgate (1978)
Hussain (1985)

Table 2

Essential amino acid content of some plant foods
(g/16g N)

Food	His	Ile	Leu	Lys	Met+Cys	Phe+Tyr	Thr	Trp	Val
Potato	1.9	4.0	6.1	5.4	2.9	7.4	3.8	1.4	5.1
Sweet Potato	1.3	3.7	5.4	3.4	2.8	6.1	3.8	1.7	4.5
Rice (White, milled)	2.4	3.0	8.2	3.7	3.7	8.8	3.4	1.3	5.3
Wheat	2.0	3.3	6.7	2.9	4.0	7.5	2.9	1.1	4.4
Beans dry	2.9	4.2	7.7	7.2	1.9	7.9	4.0	1.0	4.5

Source: Leung, et.al (1972)

Table 3 Net dietary protein calories percent of foods

Food	Net dietary protein calorie (%)
Breast milk	7.6
Oats	7.0
Potatoes	6.9
Wheat	6.1
Sorghum	4.9
Rice	4.9
Yam	4.8
Maize	4.5
Sweet Potato	3.4

Source: Cameron and Hafvander (1976)

Table-4 Nutrient content of potato (% of whole tuber)

Constituent	Raw	Boiled	Baked
Dry matter	4.7	1.9	17.7
Total N	8.3	2.9	16.7
Crude fibre	34.4	14.9	37.3
Ash	15.9	3.3	17.0
Ascorbic acid	5.0	1.1	10.5
Thiamin	1.7	0.6	7.8
Riboflavin	9.4	2.9	28.6
Niacin	4.1	1.8	15.0
Folic acid	8.0	1.6	15.2
Pyridoxine	5.6	1.7	15.6

Source: Augustin et.al (1979)

Table 5

Effect of cooking on the chemical composition of some plant food
(per 100 g edible portion)

Food	Moisture (%)	Energy (Kcal)	Protein (g)	Fat (g)	Total Carbohydrate (g)	Crude fibre (g)	Ash (g)	Ca (mg)	P (mg)	Fe (mg)	B-Caratene equivalent (ug)	Thiamin (mg)	Ribofalvin (mg)	Niacin (mg)	Ascorbi acid (mg)
Potato (boiled)	79.8	76	2.1	0.1	18.5	1.1	0.9	7	53	0.6	0-trace	0.09	0.03	1.5	16
Rice (boiled, white)	67.9	135	2.3	0.3	28.0	0.8	0.7	8	36	0.3	0	0.02	0.01	0.4	0
Maize (Porridge)	81.2	76	1.8	0.8	15.6	0.2	0.6	4	-	0.6	0	0.06	0.01	0.5	0
Bread (White)	32.7	278	8.7	1.6	55.7	2.7	1.4	24	98	1.3	0	0.09	0.05	1.0	0
Beans (boiled)	69.0	118	7.8	0.5	21.4	7.4	1.3	38	140	2.4	trace	0.11	0.06	0.7	0

Source: Paul and Southgate (1978)

Table 6 Vitamin losses in potato as a result of different methods of peeling (% of fresh un-peeled tuber).

Method	Ascorbic acid	Thiamin	Riboflavin	Niacin
Abrasion	10.5	-	-	-
Lye-steam combination	6.5	32-35	25-26	10-23
Steam	3.0	18-20	15-16	5-5.5

Source: Zobel (1979) Gorun (1978)

Table 7 Appx. losses of vitamins during domestic preparation of potatoes.

Method of preparation or processing	% Total loss of vitamins				
	Ascorbic acid	Thiamin	Niacin	Folic acid	Pyridoxine
Boiled, unpeeled	20	10	0	20	0
Boiled, peeled	20-50	0-40	0-30	10-40	15-20
Oven-baked	25	15	5	30	10
Raw, fried	30-50	10	5	20	-
Peeled, boiled, fried	40	40	40	-	-
Mashed	30-80	-	-	-	-
Hash-browned	45-70	-	-	-	-
Salad	65	-	-	-	-
Dumpling	85	-	-	-	-

Source: Augustin et.al (1978,79)

Table 8 Appx. losses of vitamins during commercial preparation of potato.

Method of preparation or processing	% Total loss of vitamins				
	Ascorbic acid	Thiamine	Niacine	Folic acid	Pyridoxine
Pre-peeled, sulphited, boiled	30	30	-	-	-
Pre-peeled, sulphited, fried	-	45	-	-	-
French fried	25-35	20-40	20	35	25
Chips	30-85	-	-	-	-
Flakes	50	>90	25	50	40
Granules	55	>90	25	50	20
Slices	40	4	73	50	72
Canned	10-70	50	50	30	30
Dices	38	4	80	30	87

Sources: Augustin et.al (1978,79)

Table 9

Composition of processed forms of potatoes (per 100 g)

Form of potato	Moisture (%)	Energy (Kcal)	Crude protein (g)	Fat (g)	Total carb. (g)	Dietary fibre (Crude fibre) (g)	Ash (g)	Ca (mg)	P (mg)	Fe (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Folic acid (ug)	Pyrido-xine (mg)	Ascorbic acid (mg)
Raw	78.0	80	2.1	0.1	18.5	1.5	1.0	9	50	0.8	0.10	0.04	1.5	14	0.25	20
Frozen french fries																
(fried)	73.1	291	3.0	18.9	29.0	3.2	-	11	77	1.0	0.09	0.02	2.1	11	0.39	12
(heated)	52.9	220	3.6	8.4	33.7	0.7	1.4	9	36	1.8	0.14	0.02	2.6	-	-	9
Frozen mashed (heated)	78.3	93	1.8	2.8	15.7	0.4	1.4	25	42	0.6	0.06	0.04	0.7	-	-	4
Chips	2.3	551	5.8	37.9	49.7	11.9	3.1	39	135	2.0	0.20	0.07	4.7	20	0.89	17
Potato flour	7.6	351	8.0	0.8	79.9	1.6	3.7	33	178	17.2	0.42	0.14	3.4	-	-	19
Flakes (prepared: water, milk, fat added)	79.3	93	1.9	3.2	14.5	0.3	1.1	31	47	0.3	0.04	0.04	0.9	-	-	5
Granules (prepared: water, milk, fat added)	78.6	96	2.0	3.6	14.4	0.2	1.4	32	52	0.5	0.04	0.05	0.7	5	0.18	3
Canned (solids only)	84.2	53	1.2	0.1	12.6	2.5	-	11	31	0.7	0.04	0.03	0.7	11	0.16	13
Canned (solids and liquid)	88.5	44	1.1	0.2	9.8	0.2	0.4	4	30	0.3	0.04	0.02	0.6	-	-	19

Source: Paul and Southgate (1978), Pelletier et.al (1977), Watt and Merrill (1975).

Table 10 Chemical composition of some Pakistani commercial potato products

Samples	Moisture %	Protein	Fat	Ash
			% dry basis	
Golden chips	3.4	4.8	43.0	3.1
Nimko	4.8	4.4	45.6	2.3
S.B. Chips	3.3	4.9	43.4	1.5
Pak Potato Chips	3.2	5.3	42.0	2.3
Pak Potato Spicy	3.6	5.3	47.0	2.4
Bingo	3.0	7.0	18.6	4.6

Source: PARC annual report (1985)

IMPROVEMENT OF WHEAT PROTEIN BY SUPPLEMENTATION WITH POTATO FLOUR

By

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The supplementary effect of boiled potato on the protein quality of wheat at 10% dietary protein level in weanling rats was studied. In the supplemented diet wheat supplied 75, 50 and 25% protein while the rest was supplied by potato protein. The true protein digestibility (TD), net protein utilization (NPU), biological value (BV) and net dietary protein calories percent (NDpCal%) of supplemented diets varied between 84-85%, 53-63%, 64-74% and 6.5-6.9% respectively. Highest protein quality was obtained when 50% of protein of the diet was derived from each of the component. This mixture had a BV of 74% and was 30% higher than wheat (57%) and 18% higher than potato (63%) when each fed alone. TD of wheat protein was lowered by supplementation. NDpCal% values indicate that supplemented diets can meet the protein requirement of children and adults.

Key words: Supplementation, wheat flour, potato protein, true protein digestibility, net protein utilization, biological value, net dietary protein calorie percent.

1. Introduction

Among the various problems emerging out as a consequence of rapid population explosion, the problem of food particularly of good quality protein is reaching critical proportion, affecting most adversely the health and vitality of the nation.

Cereals constitute main staple of the Pakistani diet. According to the micro-nutrient survey of Pakistan¹, wheat contributes 84 percent of the total cereal intake and provides 51 and 60 percent of the total calories and protein consumed respectively. Wheat protein lacks the balance of essential amino acids required for its complete biological utilization². According to Khan³, the order of limiting amino acids in wheat protein is lysine, threonine and valine. Mixed human diets, breakfast cereals and baby foods based on wheat have been shown to be deficient in lysine^{4,5}. The protein quality was lowered in wheat varieties having higher content of protein^{2,6}. On the other hand, the protein content of potato is comparable, on a dry basis, with that of the cereals. The biological value of this protein, being rich in lysine, is high⁷ and equals to that of egg protein when fed as a sole source of protein to man⁸. Some work on the improvement of wheat protein by supplementing with milk, fish, legumes and leaf protein has been done⁹⁻¹⁴. There is no information available on the supplementary effect of potato consumed in Pakistan, on the protein quality of wheat. In this paper the effect of

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different levels of boiled potatoes on the protein quality of wheat as measures in rat assay has been reported.

2. Experimental

2.1 Selection and preparation of diets

Wheat (Pak-81) and Potato (Cardinal) were procured from wheat programme and Pak-Swiss Potato Development Project, National Agricultural Research Centre, Islamabad. wheat was ground to whole flour by using Cyclotech mill. The potatoes were boiled in open pan for 45 min, peeled, mashed, freeze dried and analyzed. The experimental diets (Table 1) were prepared by mixing wheat flour and potato flours with corn starch to calculated protein levels of 10 percent. A protein free diet consisting of corn starch 58%, potato starch 10%, glucose 15%, vitamin and mineral mix 2%, was included to measure metabolic faecal nitrogen.

2.2 Chemical analysis

The chemical composition of wheat and potato flour diets was determined according to standard method¹⁵. The caloric value was determined in Ballistic Bomb Calorimeter.

2.3 Biological evaluation

The experimental procedure has been described by Khan and Munira¹⁶. Forty eight weanling Albino rats, weighing between 50-60 g were grouped by randomized block design. Each group consisted of four rats (male and female) housed in a screen mesh bottomed cage, a sheet of filter paper was placed under each cage for the collection of faeces. The experimental diets were randomly assigned to these groups in such a way that each diet was fed ad libitum to two group of rats for a period of ten days. Gains in body weight were recorded daily.

At the end of experiment the rats were killed with chloroform. Incisions were made into skull, thoracic and abdominal cavities and the carcasses of each group were dried to a constant weight at 105°C. Dried carcasses were weighed and ground in an electric grinder. The nitrogen content of diets, faeces, and carcasses of each group was determined by using Kjeltac auto analyser. Net protein utilization was estimated according to the method of Miller and Bender¹⁷.

$$T.D(\%) = \frac{\text{Nitrogen intake} - [\text{Faecal nitrogen} - \text{metabolic nitrogen}] \times 100}{\text{Nitrogen intake}}$$

$$B.U \% = \frac{\text{Net protein utilization}}{\text{True digestibility}}$$

Net dietary protein calorie percent (NDpCal%) of diets was calculated according to Miller and Payne¹⁸.

3. Results

Table 2 shows the average values for true protein digestibility, net protein utilization, biological value and net dietary protein calorie percent.

3.1 True protein digestibility (TD)

The TD of wheat protein was highest (90%) and it decreased significantly by supplementation with potato protein. The TD of supplemented diets ranged from 84-85%. The average TD of boiled potato was 85%.

3.2 Net protein utilization (NPU)

NPU increased from 51% in wheat based diets to 55, 63 and 53% respectively in diets supplemented with 25, 50 and 75% potato protein. The NPU of diet containing 100% protein from potato was 54%. The NPU of the diet containing 50% protein from wheat and 50% from potato was the highest.

3.3 Biological value (BV)

The BV of wheat and potato protein was 57 and 63% respectively. The BV of diets increased to 65, 74 and 64% when wheat and potato protein were mixed in ratio of 75:25, 50:50 and 25:75 respectively.

3.4 Net dietary protein calorie percent (NDpCal%)

The NDpCal of diets based on wheat and potato was 6.1 and 6.5% respectively. The NDpCal of diets supplemented with different levels of potato ranged between 6.5 and 6.9%.

4. Present results show that maximum protein value is obtained when 50% of the protein in diet is derived from wheat and 50% from boiled potato. These figures correspond to 42 g of wheat flour and 44 g of freeze dried boiled potato with a ratio of about 1 to 1. Similar results in a mixture of wheat and lentil have been reported¹². The true protein digestibility of freeze dried boiled potato is 85% which is in agreement with the values (82.8-90.8) obtained by Eppendorfer et. al¹⁹. Similarly a value of 80% for TD of boiled potato has been reported by Khan et. al²⁰. The BV of the diet containing 50% protein from each component, presumably supplying all the essential amino acids, is 30% higher than the diet based on wheat and 18% higher than the diet containing 100% protein from potato. In Fig.1, the low NPU of diets containing 100% and 75% protein from wheat is possibly due to the fact that lysine is the main limiting amino acid in these diets. A significant positive correlation ($r = 0.92$) between available lysine and NPU of proteins with lysine as limiting amino acid has been reported¹². Similarly methionine may become the limiting amino acid when

75 or 100% of dietary protein are provided by boiled potato resulting in low NPU of the diets (Fig.1). Khan et. al¹², showed a positive correlation ($r = 0.97$) between BV and total sulphur containing amino acids. The BV of potato (63%) in the present study is higher than that of wheat which confirms that potato protein has a better essential amino acids composition than wheat protein. According to WHO²³ potato protein does not satisfy most of the amino acid requirements for infants, but it has a very high amino acid score of 90 for the pre-school child and score of over 100 for all other age groups.

According to FAO²⁴, the protein allowances for different age group in terms of NDpCa% are 8.0, 7.8 and 5.9, 8.4, 4.6 and 9.5 for infant, toddler, child (4-9 years), adolescents, adult and lactating mothers respectively. All supplemental diets in the present study have NDpCa% between 6.5-6.9 and can meet the protein requirements of children of (4-9 years), and adults only. Similar results in combinations of boiled rice and cooked lentil and wheat and cooked lentils have been reported^{4,12}. The present findings agree well with work done in human nitrogen balance experiments with potato. Lopez de Romana et.al²⁵, demonstrated that potatoes can meet the daily requirement for protein and a substantial part of that for energy of young children recovering from malnutrition. Similarly human adults were maintained in nitrogen equilibrium and good health on diets in which all the nitrogen was supplied by potatoes²⁶.

In conclusion, potatoes are useful source of protein, especially if large amounts are eaten. In combinations with other foods, potatoes can supplement diets which are limiting in lysine. In searching for higher yielding varieties, maintenance of protein level in potatoes should not be over-looked by plant breeders. The processing and keeping equality should be improved by increasing the total solid contents and reducing the level of tyrosinase enzyme, responsible for the blackening of potato during storage and before or after cooking without affecting the normal nutritional composition or texture of the potato.

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Table 1 Composition of Experimental Diets (%)

Ingredients	DIETS				
	A	B	C	D	E
Wheat flour	82.9	62.2	41.5	20.7	-
Potato flour	-	22.1	44.2	66.2	88.3
Corn starch	17.1	15.7	14.3	13.1	11.7
Total	100.0	100.0	100.0	100.0	100.0
Protein Distribution(%)					
Wheat	100	75	50	25	-
Potato (boiled)	-	25	50	75	100

Table 2 Supplementary effect of boiled potato on the protein quality of wheat

	Wheat flour	Wheat flour Potato	Wheat flour Potato	Wheat flour Potato	Potato
Protein distribution(%)	100	75:25	50:50	25:75	100
True protein digestibility (%)	90	85	85	84	85
Net protein utilization(%)	51	55	63	53	54
Biological value (%)	57	65	74	64	63
Net dietary protein calorie (%)	6.1	6.5	6.9	6.5	6.5

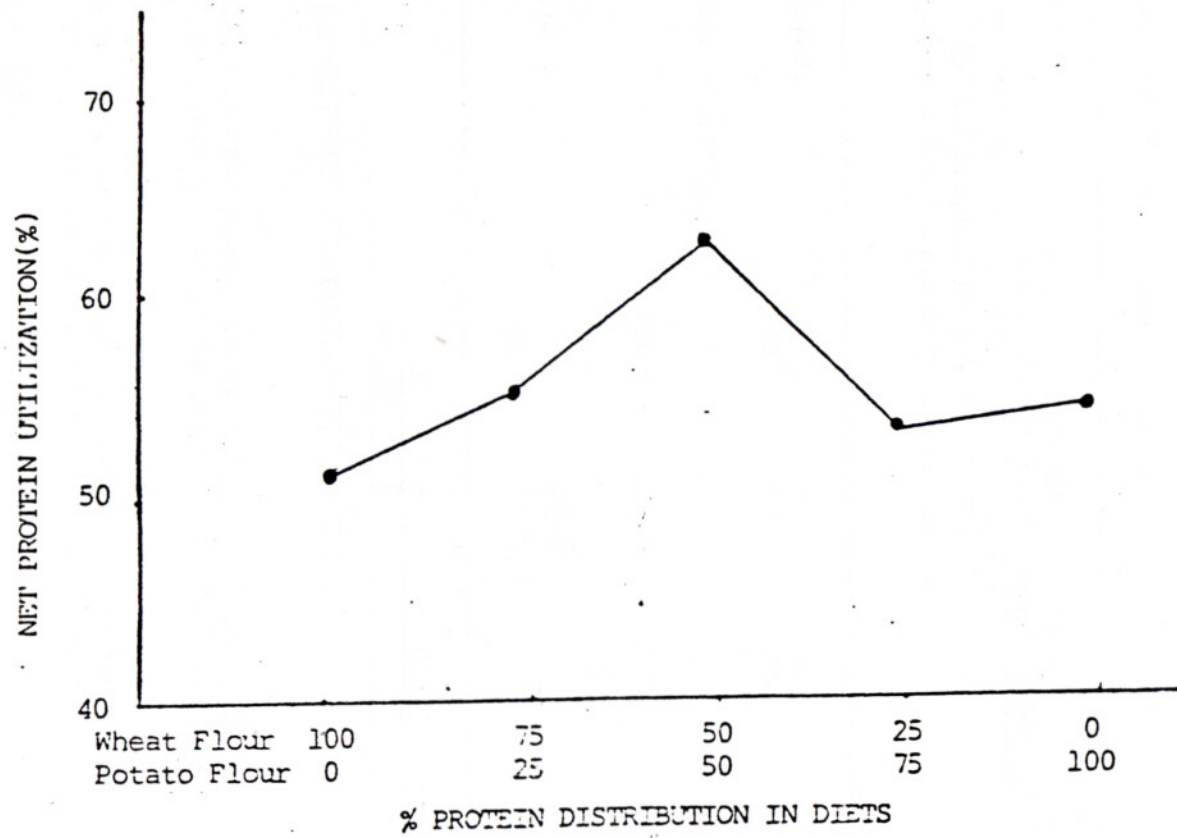


FIG. 1 PROTEIN QUALITY OF VARIOUS COMBINATIONS OF WHEAT AND POTATO FLOURS

RECOMMENDATIONS OF THE SEMINAR

1. The State Bank of Pakistan should authorise specific targets for marketing loans to be made by suitable credit agencies to enable farmers to sell their potatoes later in the year when prices are higher. This should increase producer's incomes and help even out prices over the year, which in turn, should encourage demand.
2. The feasibility of a loaning system to tackle the problem of year to year price fluctuations, with loan recovery taking place in high price years, should be studied. Such a system should be designed to reduce fluctuations in both prices and producer's incomes.
3. Procurement agencies should intervene in the market earlier to purchase potatoes at the guaranteed floor price. Poor farmers who tend to sell all their produce immediately after harvest could then benefit from the scheme.
4. The Adamjee Insurance Co. should study the feasibility of a crop insurance scheme for potatoes.
5. Consumer objection to sweetening of potatoes was found to be the major constraint to expansion of demand. To eliminate sweetening during storage potatoes for table consumption should be stored at 6-8°C instead of the present 2%. Potatoes for processing should also be stored at a higher temperature. In both cases sprout suppressant should be made readily available, its import allowed and duty on it removed. (Note that use of sprout suppressant, allowing higher storage temperature, will reduce electricity consumption, thus helping solve the country's electricity shortage problem).
6. A suitable potato variety for processing, adapted to local growing conditions, should be identified and grown on sufficient scale to meet the requirements of processors.
7. Due attention should be given to protein content and nutritional characteristics in the selection of new varieties.
8. The duty should be removed on packaging for processed potato products and on the raw material used in the local manufacture of such packaging.