Introduction

The potato (*Solanum* spp.; Figure 1) is grown in 79% of the world's countries (FAO, 1986). It is second only to maize in terms of the number of producer countries and fourth after wheat, maize and rice in global tonnage. Its importance in European countries, the USSR, North America, Australia and the Andean countries of Latin America is well known. Less widely recognized, however, is the rapid growth rate of potato production in developing countries.

FAO statistics show that the percentage increase in potato production from 1961/65 to 1979, for all developing market economy countries, was greater than 99%, while that of cereals and other roots and tubers was, respectively, only 47% and 44% (International Potato Center, 1981). Potatoes are one of the most efficient crops for converting natural resources, labour and capital into a high quality food (Horton, 1981). They can yield more nutritious food material more quickly on less land and in harsher climates than most other major crops; and the edible food material can be harvested after only 60 days.

Current and future roles

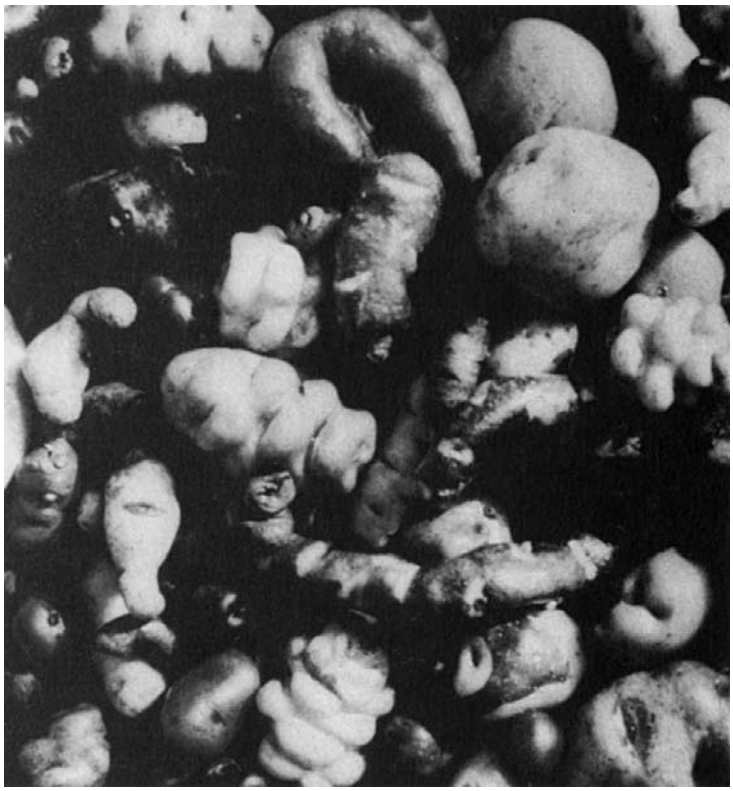
Though potatoes occupy a smaller area in most developing countries than do other major food crops, their increasing popularity has caused planners and policy makers to take a closer look at the current and future roles that potatoes may play in national food production systems.

In recent years, the enormous potential for agronomic improvement in food plants through plant breeding has been increasingly recognized. In the case of potatoes, greater attention is being focused on ways to increase production, improve storage methods and facilitate marketing. Concomitantly, there is often a need to understand and improve the nutritional contributions that potatoes can make to the human diet. How-

ever, improvements in production and nutritional understanding may not go hand in hand, and one is often sacrificed to the other.

Many workers have advocated increasing the content and quality of protein in food crops, but this aspect is now often considered to be of minor importance. Although malnutrition is recognized as a deficiency in both energy and protein supplies, efforts to improve total food production have concentrated on breeding for greater crop yield and resistance to disease. This review emphasizes the importance of maintaining the good nutritional quality of the potato, while searching for the means to increase yields and enhance disease resistance.

Figure 1. Some of the varieties in the world potato collection of the International Potato Center.



Misconceptions and a remedy

There are many local misconceptions concerning the nutritional value of potatoes. In areas where it has been regarded as a luxury crop, the potato is often considered to be a ritual food or a garnish for other major meal components and, therefore to have aesthetic importance only (Figure 2). Where consumed as a complementary vegetable with staple food items, potatoes are often wrongly believed to make a negligible contribution to the nutritive value of a meal. Even where the potato is regarded as a staple food, it is usually seen only as an energy source and there is little awareness of its vitamin or protein content.

Obtaining factual information to correct these misunderstandings is difficult for government planners and workers within national potato programmes. Articles on potato nutritional quality are numerous, but most deal only with one specialized area of research. Reviews covering all aspects of the subject are extremely scarce and in most cases rather superficial. Furthermore, the journals in which either specialized or general articles appear are frequently unavailable in local libraries. Many articles address developed country interests, particularly those of the processing industry, and are therefore less relevant to the food needs of developing countries.

An outline of the book

This review is not intended to be fully comprehensive. Some aspects are mentioned only briefly since they are mainly the concerns of food scientists and technologists working in the large-scale processing industry. I have focused on the nutritional aspects of the potato in the form in which it is normally consumed in developing countries

Although the book is presented as a single unit, each chapter is written to stand alone and may be used in training courses or for other purposes. Not all the 700 titles reviewed (many of which are in the library at the International Potato Center) are cited; instead the references at the end of each chapter are those judged to be most useful or most current in respect of each chapter topic.

Chapter 1 introduces the reader to the structure and components of the potato; but does not cover all the morphology, structure and chemical reactions of the tuber in detail. These can be obtained in more specialized texts.

In *Chapter 2* the nutritional composition of the potato is compared with that of major food grains, roots, tubers and vegetables. Emphasis is on comparisons of foods, in the form in which they are usually eaten, i.e.

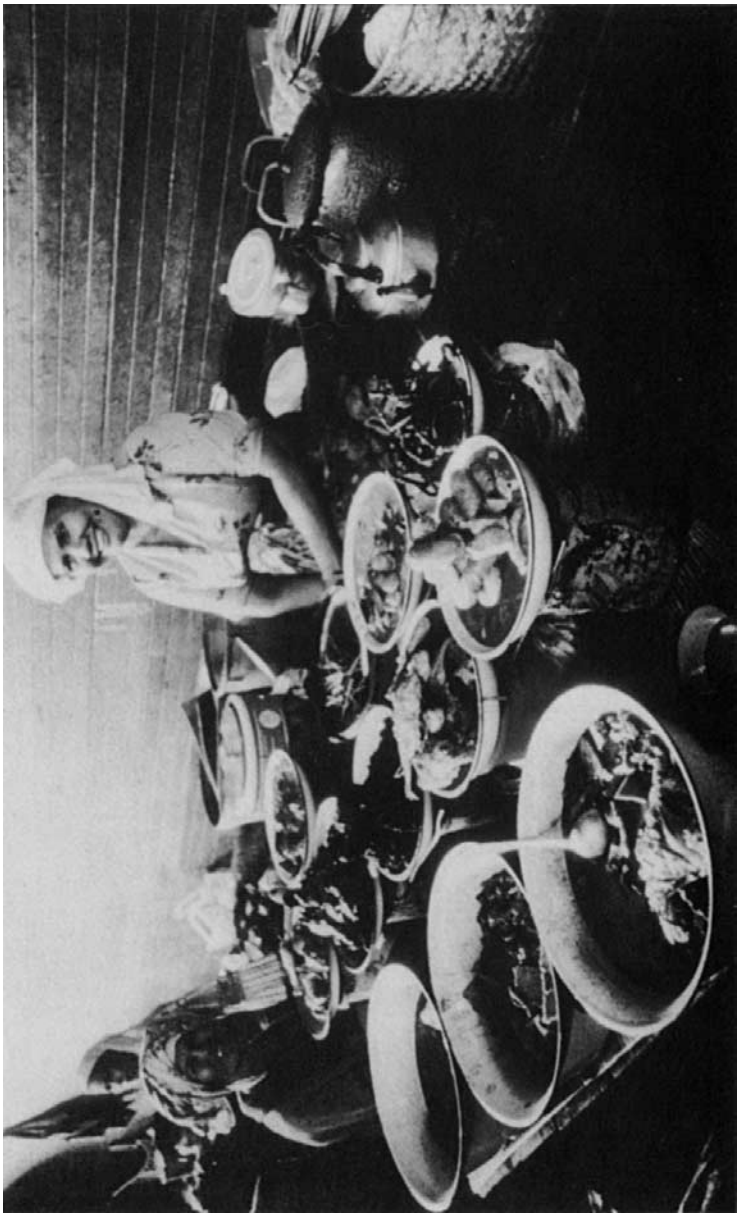


Figure 2. Potatoes appear as a garnish or flavouring in many meat and vegetable dishes offered by a market vendor in West Sumatra, Indonesia.

cooked. Contributions the potato can make to dietary energy, protein, fibre, vitamin, mineral and trace element requirements of humans are discussed. This information is necessary for policy makers and planners making decisions about the allocation of research and development funds for food production; and ranks equal in importance with comparisons of yield, time to maturity, water, fertilizer and plant protection requirements, or perishability. However, in diets foods may be mixed to provide nutritious combinations suitable to local habits and conditions, and in this chapter we consider the potato as one component of such diets.

Potato nitrogen includes both protein and non-protein constituents. *Chapter 3* deals with factors affecting tuber nitrogen concentration and composition, and discusses feeding experiments with adults and children which demonstrate the high quality of potato N in human diets. The potential recovery of potato protein from processing waste is also reviewed.

The effects of cooking, processing and storage on the nutritive value of potatoes are considered in *Chapter 4*. Each process can alter significantly some components of the raw potato tuber, particularly the vitamins. The individual methods, however, have different effects, and those causing the least damage to nutritional quality are emphasized. Although the industrial processing methods mentioned may, at present, be of little relevance to most developing countries, some countries, notably India, are engaged in increasing the number of their processed-potato products.

Chapter 5 reviews current knowledge about potato glycoalkaloids, proteinase inhibitors and lectins, which may have adverse effects on humans. Relatively little is known about the nutritional significance of these components, particularly the last two. This chapter focuses on conditions producing increases in the concentrations of these components to toxic levels. The effects are discussed and current opinions on the nature of the toxic reactions are included. Practical recommendations for controlling tuber glycoalkaloid development are featured.

The International Potato Center has sponsored a three-year study to gain more knowledge of potato consumption in several developing countries. Some of the results are included in *Chapter 6*, to provide an overview of the variety of ways potatoes are used in human diets. Attention is directed to the nutritional contribution potatoes make within certain dietary patterns and their potential contribution if these patterns are altered or if current consumption levels are increased.

Finally, although the style of the book is conventionally English, 'french fries' and 'chips' are used throughout instead of the English terms

chips and crisps, respectively. This is because it is felt that readers may be more familiar with the American usage. Also, energy values in both kcal and kJ are given throughout for the reader's convenience.

References

FAO (1986). *1985 FAO production yearbook*, vol. 36, pp. 126–7, FAO Statistics series no. 47. FAO, Rome.

Horton, D. (1981). A plea for the potato. *Ceres*, Jan–Feb: 2832.

International Potato Center (1981). *World potato facts*. International Potato Center, Lima.

1

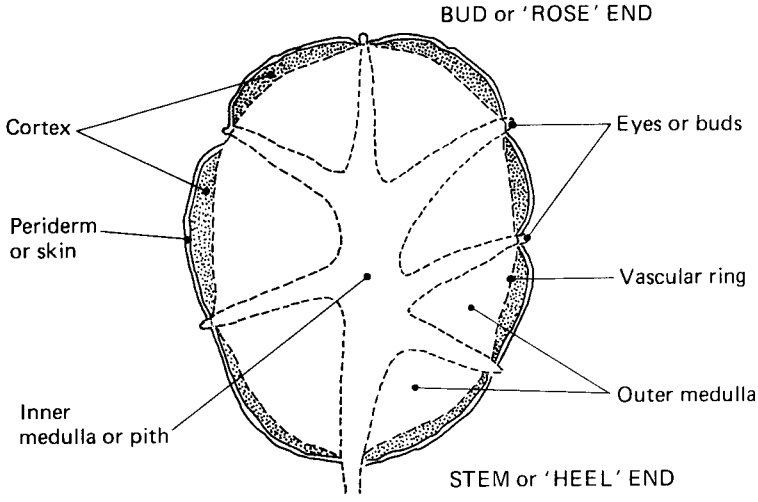
Structure of the potato tuber and composition of tuber dry matter

Structure of the tuber

The potato tuber is not a root, but the enlarged apical portion of a lateral underground branch called a stolon. Externally, the tuber clearly shows its relation to the aerial stem. The spirally arranged eyes, from which sprouts arise, are formed by the base of a rudimentary leaf scale with three buds in its axil. The eyes may be shallow, medium or deep, depending on the plant variety. Figure 1.1 shows the organization of the principal internal tissues of the mature tuber.

The outer layer of single cells of the tuber apex, the epidermis, is usually colourless; but red and purple anthocyanin pigments are found in the periderm, which is a corky layer usually known as the skin.

Figure 1.1. Cross-section of the potato tuber showing internal structure.



The region immediately inside the periderm extending inwards to the vascular ring is the cortical layer. This consists of two parts: that next to the skin is the cortex proper, usually not more than about 2 mm thick; between it and the vascular ring is a layer of storage parenchyma. The true cortex and the outer storage parenchyma are usually bracketed together as cortex. The total cortical layer is of variable thickness, usually 0.3 to 1 cm, but is negligible at the eyes and point of attachment. Inside the vascular ring is another layer of storage parenchyma called the outer medulla. The more translucent, wetter part in the centre of the potato is the inner medulla or pith. Table 1.1 gives the proportion of the whole potato in each major zone. Variations are considerable, owing to difficulties of defining the boundaries exactly and to differences between tubers.

The cell structure is relatively simple, consisting primarily of individual cells with cellulose walls cemented together with pectins. Inside a cell is the nucleus and the cytoplasm, which is the seat of processes such as respiration and starch synthesis. Some components such as starch grains are visible under the microscope as distinct inclusions in the cytoplasm; others are in solution in the cell sap.

Dry matter

Factors affecting the yield and content of potato tuber dry matter (DM) have been reviewed at length by Burton (1966) and more briefly by Grison (1973). DM content is extremely variable: a range of 13.7% to 34.8% was found amongst accessions to the germ plasm collection at the International Potato Center (unpublished data). Factors, other than variety, which influence DM include cultivation practices, climate, length of growing season, soil type, and pests and diseases.

Analyses of a number of varieties all show the same trend in distribution of DM: the percentage increases from the periphery inwards as far as the

Table 1.1. *Percentage contributions of the major parts of whole tubers*

Peel	Cortex	Outer medulla	Pith
5.9	33.0	35.4	25.7
2.8	52.2	31.3	13.7 (Small potatoes)
2.8	37.0	40.0	20.2 (Large potatoes)

Percentages as shown by Chappell (1958).

inner cortical tissue and outer medulla, and decreases from there to the centre. In other words, the bulk of the DM is contained in the storage parenchyma. In addition, there is a gradation of DM content from the 'heel', or attachment end, to the 'rose', or bud end, the former containing the higher percentage (Burton, 1966).

DM content is usually measured by specific gravity. The method is simple and rapid; Schéele *et al.* (1937) demonstrated a high correlation between DM and specific gravity when a large number of samples (560) was employed. However, the reliability of the relationship between specific gravity and total solids may be reduced when individual tubers containing intercellular air tissue spaces or the phenomenon known as 'hollow heart' are included in the measurements (Porter *et al.*, 1964; Burton, 1966). Also, the regression lines calculated for the relationship can vary with factors such as soil type, growing conditions, location (Porter *et al.*, 1964; Schippers, 1976), and even cultivars (Schippers, 1976). It has therefore been recommended that situation-specific regression lines be used.

The approximate composition of potato DM is given in Table 1.2, and

Table 1.2. *Approximate composition of potato tuber dry matter*[a]

Constituent	% in DM	
	Normal value (approx.)	Range (approx.)
Starch	70	60–80
Sucrose	0.5–1[b]	0.25–1.5[b]
Reducing sugars	0.5–2[b]	0.25–3[b]
Citric acid	2	0.5–7
Total N	1–2	1–2
Protein N	0.5–1	0.5–1
Fat	0.3–0.5	0.1–1
Fibre (dietary)[c]	6–8	3–8
Ash	4–6	4–6

[a] Source of all data, except those for dietary fibre, was Burton (1966).
[b] Figures represent mature, unstored tubers. Sugar content is affected by stage of maturity and temperature of storage. It is quite possible for total sugar content of potatoes stored at −1 °C to be 30% of DM and for that of unstored immature tubers to be more than 5% of DM (Burton, 1966).
[c] Calculated approximately from data given by authors mentioned in Chapter 2, pp. 38–9.

its various constituents will be described briefly. The nutritional significance will be discussed in Chapter 2.

Carbohydrates

Potato carbohydrates may be classified as starch, non-starch polysaccharides, and sugars.

Starch

Starch normally constitutes the greater part of the DM, and levels are modified by factors affecting the DM content of the tuber. Distribution of starch follows that of the DM, increasing from the skin inwards as far as the vascular ring and then decreasing inwards to the central medullary region, while the 'heel' end contains more starch than the 'rose' end.

Starch is present in the form of granules, consisting of amylopectin and amylose in a fairly constant ratio of 3:1. Amylopectin is a large, highly ramified molecule containing approximately 10^5 glucose residues. The amylose molecule is smaller, containing about 5000 glucose residues linked mainly by unbranched α-1,4 links, although slight branching sometimes occurs. There are small amounts of phosphorus, combined chemically with starch, most of it in the amylopectin fraction. The presence of phosphate appears to inhibit the complete enzymic breakdown of starch by β-amylase and affects the viscosity of gels prepared from potato starch (Burton, 1966).

When potatoes are subjected to heat in cooking or processing, the water they contain is absorbed into the starch granules, and at temperatures of 70 °C and above the starch is gelatinized. The resulting gel usually remains inside the potato cells unless these are ruptured during cooking or other processing treatments such as mashing, in which case the release of starch from the cells may make the cooked potato sticky.

This high starch content has made manufacture of potato starch economically feasible in developed countries. Such starch gels set rapidly and have a high hot-paste viscosity, unlike those from cereal starches. Potato starch is used in the manufacture of adhesives, in the textile industry, in the food industry and for the production of derived substances such as alcohol and glucose.

Non-starch polysaccharides

The non-starch polysaccharides comprise only a small part of the tuber DM: for example, Hoff & Castro (1969) found 5.6% on a dry weight basis (1.2% on a fresh weight basis) of cell wall–middle lamella material