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1. GENERAL INTRODUCTION

1.1. Background

Present food production is still sufficient to feed every world citizen adequately, although the production areas, types of plant and total production vary by region. Some parts of the world are surplus whereas the other parts are facing food supply problems. This is clear from the substantial increases in per capita food supplies achieved globally and for a large portion of population of the developing world. Nevertheless, parts of South Asia may still in difficult situation and much of the Sub-Saharan Africa will probably not be significantly better and may possibly be even worst off than at present in the absence of concerted action by all concerned (FAO 2000). It is well known that there are significant regional differences with respect to style of consumption and types of food which dictating the agricultural production practices.

In general, the world has been making progress towards improved food security and nutrition. However, in the long run total food production can not keep pace with the rapid population growth. Agricultural research is fundamental in meeting the challenge of increasing food production faster then population growth. The nutritional situation of many countries in Asia and Africa is a deal worse than 20 to 30 years ago. A projection of 25 years ahead shows that food production has to double to ensure sufficient food for everyone (FAO 2000). Many efforts has been done through research that focus on increasing productivity through different methods such as a set of technology known as the “green” revolution and application of breeding technologies include genetic engineering.

Human has been used thousand of plant species for several purposes since long time ago. About hundred have been developed into important crops (Hill et al. 1998) and only few of these crops have been intensively used in the world agriculture. This situation will create genetic erosion of many valuable plants and lead to reduction of genetic variation within and between species, and at the end limits the opportunity to introduce new, sustainable and high yielding crops for the future. These concerns have generated awareness and interest of scientist to preserve biodiversity of plants that can be used as sources for genetic improvement and direct or indirect use as food or non-food, through research on wild plants and under-utilized crops or neglected crops. In the past, increase of yield has been the most important goal of agricultural production system. Meanwhile, many agricultural scientists are trying to produce plants with specific characters e.g. resistant to pests and diseases, drought tolerance, or plants having higher specific nutritional characters such as high lysine content, high sugar content etc.

Tropical root and storage roots crops such as cassava, sweet potato, aroids, yam bean and wild mung bean are food crops of major importance in tropical area. In general, these crops have until recently received much less attention from research workers than tropical cash crops such as wheat, corn and rice. Agricultural science has developed faster in Western Europe and United States of America because these groups of developed countries are able to provide variety of support in any means for universities and the researchers. Moreover, such grain especially wheat and corn have been well adapted and used as the main sources of food energy by most of the population since long time ago.

Conventional root crops such as cassava, sweet potato, yam and taro are extensively grown in different countries in tropical area of Africa, Asia and South America. In areas where root and storage roots are the main source of nourishment, the local population often suffers from protein deficiencies. However, it is quite incorrect to generalize because the individual species differ greatly in protein content. Some of storage roots crops have protein contents comparable with those of cereal grains when calculated on a dry-weight basis.

Among food crops, the tropical legume root crops of yam bean (*Pachyrhizus spp.*) and wild mung bean (*Vigna vexillata*) have been particularly neglected. These potential root crops are till now, to a large degree, unimproved by selection and breeding, although as a root crops they might provide high yields as well as high yield stability (Grüneberg, personal communication 2003) and as a legume they have the advantage of legumes family, having soil bacteria belonging to the genus *Rhizobium* in their roots nodules which are able to convert nitrogen gas from the air into forms usable by the plants and even enrich the soil in which they are grown, as well as to produce protein rich food and improve sustainability in cropping systems (NRC 1979, Sørensen 1996).

1.2. Botanical description and distribution

Yam bean (*Pachyrhizus* Rich.ex DC) is a legume storage roots crop belongs to the family *Fabacea,* and subfamily *Faboidae.* The name *Pachyrhizus* comes from the Greek *Pachys* = thick and rhiza = root (Lackey 1981, Ingham 1990, Sørensen 1988 and 1996). The genus comprises three cultivated species and two wild species. The cultivated species have different ecogeographical origin: *P. ahipa*, from the highland tropics of Bolivia and Northern Argentina; *P. tuberosus*, from the tropical lowland of both sides of the Andean mountain; and *P. erosus*, from semi-arid tropics of Central America. The two other wild species, *P. panamensis* and *P. ferrugineus*, are also of South America origin. *P. erosus* was introduced to Asia by the Spaniards and later became widely cultivated in South East Asia. It is also found in India, China and East Africa (Sørensen et al. 1996, Sørensen 1988 and 1996).

1.3. Pruning and yield potential

All cultivated species are usually grown as annual crops, although the plants have a perennial habit. In both *Pachyrhisus ahipa* and *Pachyrhisus erosus,* reproductive pruning - the manual removal of fertile shoots - is generally practised to increase tuberous root growth (Sørensen 1996). In *Pachyrhizus tuberosus,* not only the flowering shoots are pruned, but up to a third of the vegetative shoots are also removed. All the species in the cultivated genus are mainly reproduced generatively by seed annually, but it could be multiplied vegetatively by cuttings or in the case of multi tuberous genotypes, also from storage roots. The storage roots of yam bean are harvested when checks shows them to be large enough. Early harvest yields watery and succulent storage roots while late harvest yields roots with higher starch content. Harvesting time is decided depending on the storage roots's size which is required by the consumers (Sørensen 1994 and 1996).

Pachyrhizus ahipa

Ørting et al. (1996) report that storage roots weights of 1000 to1500 g are preferred in Bolivia where the fresh storage roots yield varies from 12 - 30 t ha^{-1}. On an experiment in Portugal, yields of fresh tuberous roots ranged between 29 and 50 t ha^{-1} with dry matter percentage of 19 - 25% (Vieira da Silva 1995, Castelanos et al. 1997).

Pachyrhizus tuberosus

There are very few results available from field trials evaluating the yield of this species. Duke (1981) found that yield performance of *P. tuberosus* roots ranged between 7 and 10 t ha^{-1}. In fertile soil, yields of 30 t ha^{-1} are quite possible during the first year of cultivation. The fleshy storage root of jicuima can weigh up to 3-4 kg (Munos Otero 1945, Menezes and Oliveira Nunes 1955 in Sørensen 1996). Nielsen et al. (1999) found that pruning practices give significantly different storage roots yield. In pruning plants they got 27.2 - 27.3 t ha^{-1} fresh storage roots whereas unpruned plants gave only 15.4-16.3 t ha^{-1}. The highest yield so far recorded (70.3 t ha^{-1} in the 1993 season and 52.9 t ha^{-1} over several consecutive seasons) was obtained in Benin (Adjahossou and Sogbenon 1994). In Tonga, the three highest yielding accessions gave 103.5 t ha^{-1} (a landrace of Brazilian origin) and 80.4 and 43.4 t ha^{-1} (two jiquima landraces from Ecuador) (Adjahossou and Ade 1998).

Pachyrhizus erosus

In Mexico, the average yields obtained in flood-irrigated field in the Bajio region of the state of Guanajuato were 60 - 80 t $ha^{-1.}$ The fresh storage roots weight in dry land ranged from 35 to 60 t ha^{-1}. In field trials in Mexico (flood irrigated), Costa Rica (dryland) and Tonga (dryland), record yields of 100 -145 t

ha^{-1} (fresh storage roots) have been repeatedly obtained. From these experiments, the constantly high yield of the Mexican cultivars was confirmed (Heredia and Garcia 1994, Nielsen 1995 and Morera 1994). However, from India, Ramaswamy et al. (1980) reported high yields about 140 -186.6 t ha^{-1} in two best Mexican lines.

1.4. Utilisation

Pachyrhizus ahipa

The storage roots are locally considered as fruit rather than a vegetable, and are therefore sold on the street or at the market by fruit rather than vegetable vendors. It is generally consumed raw, as an apple-like snack, sliced and served mixed with vegetable in local dishes, or prepare as juice (Ørting et al. 1996).

Pachyrhizus tuberosus

The storage roots of the jicuima cultivar group, with white-cream coloured flesh, and also the ahipa cultivar group are eaten raw or cooked as a vegetable. The extremely succulent, crispy and tasty storage roots can also be used to make a refreshing ‘fruit’ juice. In the case of jicuima storage roots, the fruit juice may be mixed with milk. Chuin storage roots are cooked and eaten often in the same way as the common staple food manioc (Sørensen 1996).

Bertoni (1910) (in Sørensen, 1996) reported that the Indians at the Parana River (Paraguay) used an extract of *P. tuberosus* leaves as an insecticide. Fresh pods / legumes grounded or chewed and mixed with lard may be used as an ointment to cure itching.

In Brazil, the cooling effect produced by consumption of storage roots is believed to inhibid various kinds of fever. The starch is commonly used in the preparation of lemonades to treat infections of the bladder and various ailments of the urinary system (Sørensen 1996).

The juice obtained from the storage roots is considered as an effective diuretic and is commonly used in the treatment of nephritis (Peckolt 1922, in Sørensen 1996). In Ecuador, some people believed that consuming ahipa has an effect on improving lactation in breast feeding mothers and a curative effect on digestive ailments in children (Sørensen 1996).

Pachyrhizus erosus

In Mexico, the storage roots are used in different ways: As a fruit, - fresh storage roots are cut into sticks and sprinkled with limejuice and chilly. As a vegetable - fresh storage root slices are used in various salad dishes. Besides the storage roots, the young pods or beans are also used for human or animal consumption. The dried hay that remains after harvest provides a source of animal fodder. It is commonly mixed with lucern and maize hay before used. The rotenone content of the hay does not reach anti-nutritional levels, but at higher concentration this compound is toxic (Sørensen 1996).

In Thailand, not only the storage roots of the yam bean are used as food, but also the young pods are eaten as substitute for French bean and are said to have a pleasant taste (Ratanadilok et al. 1998).

In India, Bhag Mal and Kawalkar (1982) reported that once they are cooked, the young pods may be used as a vegetable in the same way as French bean. They further recommend the use of storage roots in the preparation of pickles and chutney, and in the preparation of a tasty drink called ‘kheer’, containing storage roots gratings boiled in milk.

In Indonesia and Malaysia, *P. erosus* is known as vegetable crop. The fresh young storage roots are sliced and mixed with other immature fruits in a pungent sauce. This traditional dish is known as ‘rujak’, usually sold by street vendors (Sahadevan 1987, Hoof and Sørensen 1989). Nowadays, the storage root has been transformed to different food and non-food products for sale in modern, commercial environment. Salted and sweetened root slices in bottle or can, yam syrup and juice are common in food shops. Some cosmetic products such as yam bean face tonic (produced by Viva Cosmetic Indonesia), yam bean masker and powder called ‘Bedak dingin’ (produced by Mustika Ratu Indonesia) are also available. As animal feed, Nuraini and Mirzah (2001) recommend using up to 12% of yam bean leaves in broiler diet. Tadera et al. (1984) and Sørensen

(1996) reported that yam bean starch of *P.erosus* is highly digestible and is therefore suitable for application in diets to treat a range of indigestion symptoms.

The demand of storage roots is steadily increasing. It is available in large stores of South and North America and also in some European countries (Sørensen 1996). It is also a favourite food in South East Asia and the Philippine islands where it is appreciated for its crispness, sweet, starchy flavour and refreshment effect (Sørensen 1996). Currently in Indonesia, yam bean storage roots are considered not only as vegetable but also as a promising cash crop for more commercial purposes. Fresh *P.erosus* storage roots of 30-40 t has been traded from Java to Bali per day (Karuniawan 2004).

The potential yield of yam bean varies between species. *P.ahipa* was reported to have fresh storage roots yield of 29 to 50 t ha^{-1}. Fresh storage roots weight of *P. tuberosus* is lower than the other two cultivated species. Duke (1981) reported that the yield of *P. tuberosus* ranges between 7 to 10 t ha^{-1} but in fertile soils, yields of 30 t ha^{-1} are possible. Yield performance of *P.erosus* has been repeatedly obtained in the range of 100-145 t ha^{-1} fresh storage roots (Heredia and Garcia 1994, Nielsen 1995, and Morera 1994). However, in India, Ramaswamy et al. (1980) reported that two Mexican lines used in their experiment gave fresh storage roots yield of 140 to 186.6 t ha^{-1} (Sørensen 1996). Although the latter result is unique, it characterizes the crop potential.

The protein, starch and sugar contents of yam bean are found higher than in any of the major root crops, and can be used as a source of starch. If large quantities are eaten, the storage roots provide large amount of starch, a medium amount of protein and sugar, and small amount of ascorbic acid to the diet (Sørensen 1996, NRC [National Research Council] 1979).

From the yields figure and use of these storage roots so far, it is clear that this potential food crop is under-utilised, although it yields out many conventional root crops. It is in many countries a neglected food crop although it has some advantages which conventional food crops does not have. It has relatively higher protein content (9.87%) than conventional storage roots crops (Evans et al. 1977, NRC 1979, Zanklan 2003) such as cassava (2.6%), yams (7.2%), sweet potato (5.4%), and potato (9%) (Rehm 1991).

The low dry matter content of storage roots is the main downside of yam bean as food crop. The average storage roots dry matter content was 13.5 % in *P.erosus*; 20.5% in *P.ahipa* and 21.1% in *P. tuberosus* (from various authors compiled by Sørensen 1996). However, Sørensen et al. (1997) observed a new yam bean type within *P. tuberosus* that has higher dry matter content between 24-28%. This Chuin type from the tropical lowland of Peru is consumed like manioc. This important finding has lead to the conclusion that the yam bean might be developed into widely adapted protein rich staple root crops (Grüneberg et al. 1998).

1.5. Objectives

To develop the quality and broaden the utilization of yam bean in different aspects, basic information and data about the composition of the eaten part (storage roots) are needed. Understanding of the physical and chemical characteristics of storage roots component is important for the evaluation of the processing quality of storage roots as raw material for various food and non-food applications and also as information for breeding program. Accordingly, this research is aimed to provide basic data on physical and chemical characteristics that determined the quality and some nutritional aspects of storage roots of yam bean and wild mung bean as described in the following objective:

- To characterize and evaluate the composition and processing properties of storage roots of different yam bean (*Pachyrhizus spp.*) species and wild mung bean (*Vigna vexillata*) grown in Indonesia and Benin.
- Study about the possibility to replace wheat flour with flour obtained from yam bean storage roots in food products.
- The results should give information's about some characteristics of the plant storage roots quality traits, which can be used as certain nutritional resources, raw materials for industrial applications, and information for breeding program.

1.6. References

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