CASSAVA (*MANIHOT ESCULENTA*) CHARACTERISTICS AND UTILISATION POTENTIAL FOR BIO-ETHANOL PRODUCTION

1. GENERAL DESCRIPTION:

Cassava is a plant with an underground root (tuber) and it is characterised as a highly effective producer of carbohydrates, mainly starch. A comprehensive overview of the plant is provided in reference (1).

Cassava is considered the fourth most important energy source for human consumption. It grows mainly in tropical environments. However, apart from its high starch content, the plant also contains cyanide glucosides.

The high cassava starch content invited interest from bio-fuel producers, and viability studies (2) have been reported.

2. AGRICULTURAL INFORMATION

According to reference (1), cassava may be cultivated under a large number of agricultural conditions. It is perennial, grows between 30˚ north and 30˚ south, up to elevations of 2 000 m above sea level. The average day temperatures should be at least 17˚ C at higher levels and 20˚ C at lower levels. Established plants can withstand drought periods of up to six months, but it is not resistant to long lasting floods or to soil or water with a high salt content.

Under moist tropical conditions the tubers may be harvested after six to seven months. At higher levels the period is 18 months and in subtropical areas it is two years. If conditions are favourable, 50 tonnes may be harvested per ha within 12 months. Yields of more than 10 tonnes per ha are estimated for less favourable conditions, such as in acidic soils ($pH < 4$) and where rainfall is less than 1 000 mm per annum.

The most important cassava characteristic is the combination of C_3 and C_4 photosynthetic routes. These promote carbohydrate production to such an extent that the plant was found suitable for industrial utilisation in Thailand, Indonesia and Brazil. Starch was reclaimed from the tubers, which were then dried and used as animal feeds.

3. COMPOSITION OF THE ROOT

The tuber consists of three types of tissue: the outer bark, the peel and the interior parenchyma. The latter is the edible portion, comprising about 85% of the root.

Previously the root was harvested non-mechanically, but mechanical equipment has been developed. Non-mechanical harvesting methods comprise about 30% of the production costs.

After harvesting the tubers, the physiological deterioration is rapid and the estimated edible period is about 24 to 72 hours after harvesting. Marketing of fresh roots is difficult. The deterioration after harvesting is caused mainly through the formation of phenolic compounds, which polymerise, forming blue, brown and black pigments. Up to 80 mg pigment may form per kg and the appearance of these compounds is often incorrectly confused with aflatoxins.

Mechanical damage to the tubers gives rise to accelerated tissue discoloration and deterioration. About five to seven days following the harvest, microbiological infection may lead to secondary deterioration.

Different hints for favourable storage of the tubers are provided. This information applies mainly to the marketing of fresh tubers. Industrial utilisation may require other, more innovative methods.

4. NUTRITIONAL AND CHEMICAL COMPOSITION

The composition of the parenchyma (edible) portion of the tuber is as follows (1):

TABLE 1: CHEMICAL COMPOSITION OF CASSAVA ROOT

	g/100 g	
INGREDIENT	**PARENCHYMA**	**PEEL**
Dry matter	**23 - 44**	**15 – 34**
Starch	**70 - 91**	**44 – 59**
Total sugars	**1.3 – 5.3**	**5.2 – 7.1**
Crude fibre	**3.0 – 5.0**	**5.0 – 15.0**
Ash	**1.0 – 2.5**	**2.8 – 4.2**
Protein	**1.0 – 6.0**	**7.0 – 14.0**

The composition of the parenchyma and peel differ. The most important contents are protein, crude fibre and sugars. In addition the peel contains more cyanides. Parenchyma of low cyanide cultivars contain between 30 and 100 mg cyanides per kg, while bitter cultivars may contain up to 1 350 mg per kg.

The composition is influenced also by the environment. Table 2 (1) indicates the vitamins, minerals and cyanide contents of cassava. Cyanoglucosides are present in all Manihot species. The cyanoglucoside (mainly linamarin) is broken down by an enzyme to form free cyanide. Genetic selection is used to reduce the toxicity problems in cassava.

The cassava starch characteristics are discussed, with particular mention of the gelatinisation characteristics. A low temperature of 60˚ C for initial gelatinisation and 80˚ C for final gelatinisation are mentioned.

5. CASSAVA APPLICATIONS

Reference (1) discusses the use of cassava as a basic food source in African countries. Useful information is also available on the treatment of the root for detoxification. Two products, Farisha and Gari, are discussed, indicating existing industrial utilisation.

6. INDUSTRIAL USES OF CASSAVA

An internet search was conducted to obtain the latest trends in cassava utilisation. Applications for bio-fuel production, particularly fermentation technology to produce ethanol, were found. Brief references to the respective documents follow.

Reference (2) discusses the *"Life cycle cost analysis of fuel ethanol produced from Cassava in Thailand."* The investigation found that ethanol production costs are high and that commercial application cannot succeed. If the yield per hectare could be increased and input costs (fertiliser and chemical insecticides) could be reduced, the situation would be more favourable. The combined fertiliser and chemical costs comprise 40% of the estimated $28 production costs per tonne. Bear in mind that this study was based on small farming units where 3.2 hectares were considered farm units.

Reference (3) describes a Japanese-Vietnamese agreement [Biopact, 10 March 2007] that involves the use of cassava to produce about 100 million litres ethanol per annum by 2009. The idea is that poor soil, a little water and a little fertiliser are required. The 2.6 times higher starch production compared to grain, presents the big advantage.

Reference (4) provides the estimated particulars for Indonesia and bases the calculations on figures per litre ethanol per hectare per annum.

PLANT	PLANT PORTION	ETHANOL PRODUCTIVITY (ℓ/ha/annum)
Cassava	tuber	4 500
Sweet potatoes	tuber	7 800
Sugar cane	stalk/molasses	5 000 - 6 000
Maize	grain	3 000 - 4 000
Sorghum	grain	3 000 - 4 000
Sweet sorghum	stalk	5 500 - 6 000
Sago	stalk	4 000 - 5 000
Coconut	milk	8 000 - 10 000

The reliability of these figures must be checked. If coconuts can produce this high level of ethanol yield per hectare, the crop's potential in Southern Africa should be considered based on viability studies. Coconuts are also a source of oil (for the food market and bio-diesel), de-oiled coconut (for food use) and de-oiled oil cake (for animal feed).

Reference (5) reports information issued by the Inter American Board of Agriculture (IABA) about the platform for horizontal co-operation between agro-energy and bio-fuels. These documents mention the following:

BIO-FUEL	LITRE PER HECTARE
Barley	1 000 ℓ ethanol/ha
Wheat	2 500 ℓ ethanol/ha
Maize	3 000 ℓ ethanol/ha
Sugar beet	5 000 ℓ ethanol/ha
Sugar cane	6 000 ℓ ethanol/ha

Cassava is therefore not included in the list.

Reference (6) assesses different interactions between food, feed and other uses. Five crops, maize, sugar cane, sugar beet, wheat and cassava are involved. The application of these crops, *for bio-fuels with current technology*, mean dramatic price increases by 2010 and 2020. The effects will be detrimental to cassava consumers in sub-Saharan Africa.

The impact may be mitigated if the so-called cellulose bio-fuel technology could become commercially viable. It suggests that bio-mass should be utilised too. A Japanese study on cassava (7) underlined this idea. Cassava bio-mass was earmarked as a raw material.

Dr Kobie de Ronde was contacted to obtain information from the June 2007 workshop at ARC Roodeplaat. The literature she provided indicated that the theme was the bio-technological change of cassava.

Reference (8), available on the internet, confirms international interest in determining the cassava genome as a means of ensuring increased starch production. It mentions the success of researchers at Ohio State University, working with trans-genetic cassava, yielding 2.6 times more starch than normal plants. The objective is a ‘super crop’ that will be suitable for ethanol production through CO_2 fixation and carbohydrate production.

A Brazilian research group (9) reported information about variation in cultivars and genetic studies in cassava. Their research focussed on a particular cassava clone and they tried to improve understanding of the molecular genetics of the crop.

7. COMMENTS

Cassava is a plant with particularly high starch content, having the ability to use photosynthesis to transform carbon dioxide into carbohydrates. The literature quoted here confirms that it is a crop to be considered seriously as feedstock material for the production of bio-fuel.

In addition, it is clear that the chemical/nutritional composition of cassava shows a very wide genetic variation. The plant apparently adapts easily to diverse agricultural conditions. A yield of 10 tonnes of tubers per ha is commonly reported, but the international development studies are aimed at producing yields of up to 80 tonnes per ha.

Negative aspects surrounding cassava include the fact that residual products after fermentation do not have any nutritional value. A second disadvantage is that the product grows underground and needs to be harvested at high energy costs. A third disadvantage is the short shelf life of the tubers after harvesting. Even for industrial utilisation purposes the tubers should be processed within 24 to 36 hours of harvesting.

The use of cassava as food in many countries (including African countries) may be affected by industrial demand. Attempts to utilise bio-mass, such as cassava pulp after starch extraction through cellulose fermentation, were mentioned. These are attempts to mitigate the competition between food and industry.

8. REFERENCES

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