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Strategies for Sustainable Production of Starch from Sweet Potato

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Abstract
Sweet potato (Ipomoea batatas L. Lam) belongs to the Convolvulaceae family. It is originated from southern Central America and can be easily grown in the tropical climax. The sweet potato contains high nutritional values such as carbohydrate, protein, dietary fibre, amino acids, enzymes, minerals, and vitamins. The main component in sweet potato is starch, which can be used in many food applications. The main objective of this study is to propose some strategies in designing a sustainable starch production from sweet potato. This can be done with the consideration of efficient starch production steps as well as the production of its by-products in order to minimize the wastes as well as to maximize the net profitability. The implementation of the recommended strategies in this study will hopefully ensure sustainable and feasible production of starch from sweet potato which can benefit the farmers and producers of this crop.

Keywords: Ipomoea batatas (L.) Lam, sweet potato, starch production, value-added products, process scheduling, process costing

Introduction

Sweet potato (Ipomoea batatas) is a member of the family Convolvulaceae and it can be harvested about 3.5 to 4 months after planting in the tropics (Tan, 2015; Ray and Tomlins, 2010). It has a great advantage in growing well on marginal soils such as bris, tin-tailings, acid sulphate soils and drained peat (Tan, 2015; Ray and Tomlins, 2010). Marginal soils in Peninsular Malaysia alone cover some 1.67 million hectares, with 870,000 ha of peatland and muck soils, 433,000 ha of idle paddy land, 165,000 ha of bris, 110,000 ha of acid sulphate soils and 91,000 ha of sand tailings (Tan, 2015).

Worldwide, the sweet potato production that is traded on the world market is relatively small. It is cultivated in about 111 countries with a total of 110.75 million tons produced in 2013 (Akoetey et al., 2017). Many countries, mainly grow it for the domestic consumption. China currently accounts the sweet potato worldwide production of more than seventy million tonnes (Mulderij, 2016; Wee; Akoetey et al., 2017). Second is Nigeria at 3,478,270 metric tons. Third is Tanzania at 3,345,170 metric tons. Fourth is Ethiopia at 2,701,599 metric tons. Fifth is Indonesia at 2,382,658 metric tons. Sixth is Uganda at 1,863,000 metric tons. Seventh is Vietnam at 1,401,055 metric tons. Eighth is United States at 341,910 metric tons. Ninth is India at 1,087,880 metric tons. Tenth is Rwanda at 1,080,780 metric tons (Wee, 2017). In Malaysia, the sweet potato production involved in many areas in the states of Perak, Kelantan and Terengganu. The production is reaching 26, 688 tonnes (2,505 ha) in 2013 (Yusoff et al., 2018).

Sweet potato is a highly nutritious carbohydrate food in vitamins, protein, minerals and energy content. It is rich in β-carotene, vitamin A and vitamin E. The nutritional value of sweet potatoes was the highest among several other foods (Ukom et al., 2009; Tan, 2015; Marczak et al., 2014). β-carotene, a potent provitamin A which used for nutrition and health in the developing countries. The deficiency of Vitamin A will leads to the serious health problem like eczema, cystic fibrosis, chronic diarrhea and others. Those who are risk of deficiency are pregnant women, breastfeeding mothers, infants and children (Ukom et al., 2009; Streit, 2018). Aside all the nutritional elements present in sweet potato, the main component of sweet potato is starch. Starch represents 9.3% per 100g of the sweet potato composition (Englyst and Hudson, 1996). Sweet potato starch is the potential raw material and important role in applying in many foods and non-food products such as chemical, and pharmaceutical industries. In the food industry, it used as an ingredient in some bakery products such as bread, biscuits, cake, juice, and noodles (Soison et al., 2015). Thus also used in the manufacturing of vermicelli, jelly, and other consumable products. In addition, it used as a food additive. For example, used as a thickener, stabilizer, or tissue reinforcing agent to improve foods to retain water, control water flows, and maintain food storage quality (Mu et al., 2017). While in the non-food industry products the starch is used for textiles, paper, fuel, adhesives, plastics, and paints production (Mu et al., 2017).

By considering its wide applications, commercialization of the starch from sweet potato is a smart move. In order to commercialize the starch, a proper design of the production steps is required. Besides, to ensure a sustainable starch production, the producer may want to consider utilizing all the waste produced during the operation and convert them into by-products. This strategy will indirectly assist in preserving the environment by reducing waste while making big profits. If these potential value-added products are considered in the milling and business model, it would benefit to the millers for their extra incomes. Indirectly, farmers also will get this benefit if the millers are affordable to buy their sweet potato at a higher price.

Hence, the aim of this study is to discuss two processing strategies in order to ensure sustainable starch processing from sweet potato with the consideration of the production of its by-products.

Strategy 1: Efficient starch processing steps
The sweet potato will be subjected to mechanical processes (washing, peeling, grinding and pressing). After that, it will be soaked to extract starch from the cell. Overall starch processing strategies can be illustrated in Figure 1. The resulted crude starch will be further subject to separation processes (centrifugation, sieving, and concentration, cleaning and drying) as shown in Figure 2.

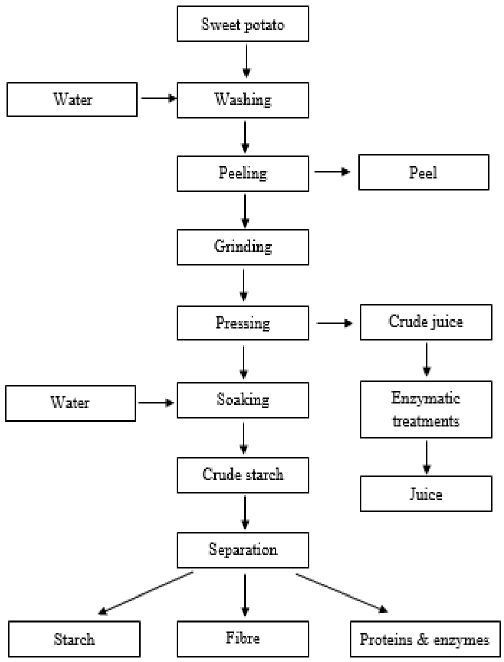

Figure 1: Overall process flow of sweet potato utilization for production of starch and value-added products.

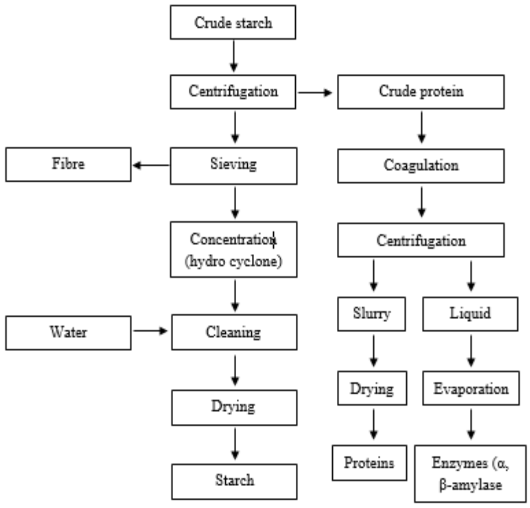

Figure 2: Flow of separation process of production of starch and value-added products.

To ensure efficient starch processing steps, a few considerations can be suggested. These may include the optimization of the whole processing steps using proper scientific procedures. Optimization of the whole processing steps may start by identifying some of the most important matters in the starch production, including the production rate and yield, critical processing steps, production cost and the outcomes of each processing step. These matters can be further re-adjust according to the producer needs such as faster processing time, higher production yield and reduction of the processing cost. These adjustments may be too costly to be implemented in a real-scale operation, hence the usage of simulation software to stimulate the real condition is recommended. This step may save some cost while ensuring the feasibility of the overall starch processing steps at different industrial scales. Some of the simulation softwares such as FlexSim, SuperPro and ProSimPlus that can be used for this purpose. For the examples, FlexSim Software has been used to study the processing of cream cheese manufacturing (Flexsim, 2012); SuperPro designer was used to model the production economics of the latest generation expression technologies on Nicotiana host plants by evaluating process unit operations and calculated bulk active and pre-dose or per-unit costs (Tusé et al., 2014); while ProSimPlus used to simulate the pasteurization process of the milk (Bon et al., 2010).

All mechanical units and operating units can be integrated and simulated. Energy and water consumption can also be considered in the design. Process sensitivity can be analyzed and process scheduling can also be developed in order to evaluate the process feasibility and its economical process design and operation.

Stage in the processing steps	By-products	Applications
Centrifugation	-α-amylase -β-amylase	Baking, brewing, preparation of digestive aids, production of cakes, fruit juices, starch syrups and glucose syrup production (Hagenimana et al.,1992; Khan et al., 2011; Dehkordi and Javan, 2012).
Peeling	-High dietary fibre. -The peel extract as an antioxidant in food systems.	-Healthy and functional food ingredient. It's used in bakery production. -It can prevent lipid oxidation in oils and meat. (Sepelev and Galoburda, 2015; Gebrechristos and Chen, 2018)
Centrifugation	Proteins	Animal feeding (Machin and Nyvold, 1991).
Pressing	Pressed juice	Healthy fermented drink (Lacto-juice) (Oke and Workneh, 2013).

Strategy 2: Production of by-products
Based on the conventional starch processing steps shown in Figure 1 and 2, there is no current commercial starch production that highly considers the recovery of some other valuable by-products that flow together in waste streams such as residual solid waste and waste water. It is expected the overall design would be different from conventional design and several additional unit operations will be needed. To design a sustainable process, by-products need to be considered in minimizing wastes as well as maximizing net profitability. Value-added products are the best strategy for farmers and millers to improve net profitability. Value-added products are highly possible to open new markets and therefore enhance the public's appreciation to the farmers. Due to sweet potato is naturally high nutritional values agricultural product, these nutritional values will accumulate in the form of by-products during the starch processing. Some of the waste generated during the starch production that can be converted to by-products as shown in Table 1.

Table 1: Potential by-products that can be obtained from the starch production of sweet potato
Beside rich of micronutrients, sweet potato is found to have endogenous α-amylase and β-amylase that would have potential to be used in related industrial purposes (e.g. Glucose syrup production) (Hagenimana et al.,1992). The β-amylase can be isolated from tuber by ammonium sulphate fractionation, indicating the specific enzyme activity could be increased as much as 24 folds (Oktiarni et al., 2015). Sweet potato consists also high dietary fibre, indicating that soluble and insoluble dietary fibre was 5.30 % and 5.43 %, respectively (Mullin et al., 1994). Dietary fibre is found to improve our digesting system and it is essential for a healthy diet. It can be also extracted and has the potential to be commercialized.

Many countries are facing problems with expensive growing demand for livestock. Alternatively, the used of rich-protein sweet potato as animal feeding has high potential (Machin and Nyvold, 1991). Besides, the juice of sweet potato can be formulated to become a healthy fermented drink (Lacto- juice) which is processed by lactic acid fermentation for their rich nutrition value, vitamins and minerals for human consumption (Oke and Workneh, 2013).

Conclusions
Two strategies have been proposed in this study in order to ensure a sustainable and feasible starch production from sweet potato. These include the considerations on starch processing efficiency and by-products production. With the consideration of both strategies, production of starch from sweet potato can be successfully commercialized at the industrial scale in order to help the farmers and manufacturers of sweet potato.

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