DEVELOPMENT OF NOVEL EXTRUDED SNACK FROM SWEET POTATO AND CORN FLOUR

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DECLARATION

I hereby declare that the materials in this thesis are original except for quotation, excerpts, summaries and reference, which have been duly acknowledged.

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ABSTRACT

The purpose of this project was to study how feed moisture content and sweet potato flour content affected the properties (colour, expansion ratio, bulk density, textural properties and sensorial properties) of corn flour extrudates. A total of six samples with various feed moisture content (12, 14, and 16%) and sweet potato flour replacement (25, 50 and 75%) was produced through a controlled extrusion process (Die barrel temperature= 120°C; feed rate= 19 kg/hr; screw speed= 200 rpm). Study found that the increase of sweet potato flour content in formulation increased the darkness, redness and yellowness of extrudates. Increase of feed moisture content and sweet potato flour content was found to increase the bulk density and hardness, but decreased the expansion ratio and crispness of extrudates. Expansion ratio was found to have strong negative correlation (-0.919**) with bulk density. Result of sensory evaluation on air cell size, hardness and compactness was found to be strongly associated to their physical analysed counterpart with correlation coefficient of 0.863*, 0.900* and 0.970** respectively. Feed moisture content did not affect the preference for all samples ($p>0.05$) while sweet potato flour only affected preference samples prepared using 12% feed moisture content ($p<0.05$). Extrudate with higher sweet potato flour content (50%) was more preferable because of better colour, more acceptable sweetness, and better crispness. Samples with 50% sweet potato flour content at 12 and 16% feed moisture content as well as sample with 75% sweet potato flour content at 14% feed moisture content were rated the highest preference amongst all samples studied ($p<0.05$) owning to better crispness and more acceptable sweetness.

ABSTRAK

*Tujuan projek ini adalah untuk mengkaji bagaimana kandungan kelembapan suapan dan kandungan tepung ubi keledek dalam formulasi memberi kesan kepada sifat-sifat (warna, pengembangan, ketumpatan pukal, tekstur dan sifat-sifat sensori) hasil semperitan tepung jagung. Sejumlah enam sampel dengan berbagai kanduangan lembapan suapan (12, 14, dan 16%) dan pengantian tepung ubi keledek (25, 50, dan 75%) telah dihasilkan melalui proses penyemperitan yang terkawal (suhu kepala die = 120°C, kadar suapan= 19 kg/jam, kelajuan skru= 200 rpm). Kajian mendapati bahawa peningkatan kandungan ubi keledek dalam formulasi meningkatkan kegelapan, kemerahan dan kekuningan hasil semperitan. Peningkatan kandungan lembapan suapan dan kandungan tepung ubi keledek didapati meningkatkan ketumpatan pukal dan kekerasan, tetapi menurunkan pengembangan dan keranggupan. Pengembangan hasil semperitan mempunyai korelasi negatif yang kuat (-0.919**) dengan ketumpatan pukal. Hasil penilaian deria untuk saiz sel udara, kekerasan dan kepadatan didapati berkait rapat dengan keputusan penilaian fizikal dengan pekali korelasi masing-masing sebanyak 0.863*, 0.900*, dan 0.970**. Kandungan kelembapan suapan didapati tidak mempengaruhi tahap kesukaan untuk semua sampel (p>0.05). Manakala, kesan kandungan tepung ubi keledek terhadap tahap kesukaan hanya didapati pada sampel-sampel dengan kandungan kelembapan suapan 12% sahaja (p<0.05). Kandungan tepung ubi keledek yang lebih tinggi mempunyai tahap kesukaan yang lebih tinggi disebabkan oleh kemanisan yang lebih diterima dan warna serta keranggupan yang lebih baik. Sampel dengan 50% kandungan tepung ubi keledek pada kandungan kelembapan suapan 12% serta 16% dan juga sampel yang mempunyai 75% tepung ubi keledek pada 14% kandungan kelembapan suapan mempunyai tahap kesukaan yang paling tinggi (p<0.05) disebabkan oleh keranggupan yang lebih baik dan kemanisan yang boleh diterima berbanding dengan sampel-sampel lain.*

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LIST OF ABBREVIATIONS

ANOVA	One-way analysis of variance
BC	Before Christ
CGIAR	Consultative Group on International Agricultural Research
ER	Expansion ratio
FAO	Food and Agricultural Association
L/D	Length/Diameter
MARDI	Malaysian Agricultural Research and Development Institute
N_2	Nitrogen
OFSP	Orange fleshed sweet potato
PE	Polyethylene
RTE	Ready-to-eat
SPSS	Statistic Programme for Social Science
SSE	Single screw extruders
TSE	Twin-screw extruder
TVP	Textured vegetable protein
w.b	Wet basis
WAI	Water absorption index
WSI	Water solubility index

LIST OF UNITS

et al.	Et Alii
g	gram
ha	hectare
kcal	kilocalorie
kJ	kilojoules
kg	kilogram
mg	milligrams
mm	millimeter
µm	micrometers
ml	milliliter
N	Newton
rpm	revolutions per minute
s	second

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LIST OF SYMBOLS

<	Less Than
>	More Than
°C	Degree Celsius
β	Beta
%	Percentage
±	Plus Minus
p	Level of Significant
=	Equal
$	Dollar
-	Negative

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Snack Food can be described as a multipurpose food which can be eaten with a meal or on the go (Edmund and Lloyd, 2001). They are generally produced from natural ingredients and sometimes with addition of components which would give certain functional properties (Ried, 1998). Snacks can be traced back to 3,000BC where snack is consumed in the form of popcorn. Snack industry valued at about $30 billion global sales at year 2000. It rose to a staggering $66 billion in global sales in year 2003 (Hodgen, 2004). The Spreading of western eating habits to the world, current busier lifestyle would catalyses increase in demand on snack food (Hodgen, 2004). The culture of eating snacks is fast incorporated into majority world population eating habits (Reid, 1998). A trend in consumer demanding snacks which is new, possessed exotic flavours and healthier content is observed (Wides, 2008). Different type of snacks have been observed especially the new generation snacks which fall into several categories such as low fat, baked but not fried, high fiber snack made from rice/wheat bran and coated snack ,etc (Bhattacharya *et al.*, 2006).

Sweet potato (*Ipomoea batatas*) ranks seventh in the most important food crop, mainly because of its versatility and adaptability (CIPotato, 2007). In Malaysia, Sweet potato is categorized as cash crops and it is the third largest produced cash crop within the country with a cultivation of 1309 hectare which produced almost 18,228 metric ton after cassava and corn (Jabatan Pertaninan Malaysia, 2010). Sweet potato is third largest cash crops in Sabah after cassava and corn at year 2009 (Jabatan Pertanian Sabah, 2009). In this millennium, there is an increase in the importance of roots and

tuber crop role to meet global food requirements, feed uses and income needs of the world's food system (Dini *et al.*, 2008). According to Villareal (1977), reason that favour the utilization of sweet potato in today diet includes the tremendous yield of sweet potato; high nutrient yield per hectare; highly dependable because of its high draught tolerance and ability to withstand typhoon conditions; acceptability by consumer due to its palatability; and low cost. Some sweet potato variety especially the orange fleshed sweep potato (OFSP) contains significant amount of β-carotene, starch, dietary fiber, protein, minerals (especially potassium and iron), vitamins (especially vitamin C, B6 and folate). OFSP also contain significant amount of antioxidant, particularly phenolic acids, anthocynins and tocopherol (Woolfe, 1992; Villareal, 1970). Sweet potato is mainly consumed as boiled roots and commonly processed into dried slices and flour to further preserve the roots for use during off-season (Bengtsson *et al.*, 2007). Processed product utilizing sweet potato which include starch, noodles, candy, desserts, and flour has been produced by farm household. Such activities are able to extend the availability, diversify the use, and increase the value-added for the sweet potato crop (CIP, 2007). Sweet potato as a starchy crop can be potentially development to be an extruded product to further extend the use of sweet potato.

Extrusion cooking can be described as a continuous cooking, mixing and forming process. It is a versatile and very efficient technology in food processing (Ilo and Berghofer, 1998). Extrusion cooking has rapidly garner popularity over traditional food processing techniques due to their technological advantage (White, 1994). Extrusion processing is versatile, has high productivity, relatively low cost, and has better energy efficiency and the less effluent (Atlan *et al.*, 2007). One key difference between extrusion cooking and conventional cooking method is the addition of intensive shear force act upon the raw materials (Ilo and Berghofer, 1998). Extrusion cooking has been used extensively in producing food and food ingredients products such as snacks, breakfast cereals, baby food, flat bread, meat and cheese analogues, modified starch and special flour (Anderson *et al.*, 1969; Bouzaza *et al.* 1996; Fast,

1990; González *et al.*, 2000; Guy and Horne, 1988, Harper; 1989; Meuser and Van Lengerich, 1992). In extrusion cooking within an extruder, the food material is conveyed and subjected to heat, mechanical work and compression, then forced through a discharge die (Friis and Cheng, 2010). Upon extrusion cooking, the food material will undergo a number of physiochemical transformations which include starch gelatinization, protein denaturation, formation of complexes between amylase and lipids, degradation of vitamins, pigments, etc (Ilo and Berghofer, 1998). Chinnaswany and Hanna (1987) and Lue *et al.* (1994) has reported that extrusion cooking are easily implemented, able to achieved better homogenization of raw material, able to produce more hygienic extrudates, less waste and environmental friendly.

The properties of the extruded product is influences by several parameters, namely the type of extruder, screw configuration, feed moisture, and temperature profile in the barrel session, feed rate, die geometry, screw speed and product properties (Aisworth *et al.*, 2004; Meng *et al.*, 2009). There are many types of extruders, low-shear, high shear, single screw, co-rotating twin screw, counter-rotating twin screw and many more which caters to producing different types of product. Screw configuration consist of a series of repeated conveying and mixing elements which include feed screw, single lead screw, reverse and forward paddle configuration as well as orifice screw. Die comes in every imaginable shapes and geometry depends on what product shapes desired (Frame, 1999). Feed moisture relates to the water content in the raw materials; while screw speeds relates to how fast the raw material is conveyed along the barrel; feed rate is the speed of the raw material input into the extruders. Temperature profile is the control of temperature across the barrel which can generally divide into two categories. Autogenous extruders generate heat through mechanical conversion (shearing) without additional heating or cooling system. And the isothermal extruders which have precise temperature control on individual barrel section with heating and cooling system (Frame, 1999). Studies on extrusion cooking usually done with the combination of two to four of the parameters explained above. Such studies

are demonstrated by researchers like Bhattacharya *et al.* (1996); Bhandari *et al.* (2005); Ilo and Berghofer (1998); Maskan *et al.* (2008); Hagenimana *et al.* (2005).

Extrusion cooking technology can be considered the most widely used processing technique to produce snack food (White, 1994). Cereals, Starches and/or vegetable proteins are the main ingredients used to produce extruded food (Anton *et al.*, 2008). The importance of these food ingredients is to give structure, texture, mouth feel, bulk, and many other characteristic which are desirable for a specific finished product (Tahnoven *et al.*, 1998). Specific attributes of a snack product is what determined the acceptance of consumer. The various sensory quality attributes of snack includes appearance, taste, colour, flavour and texture. Among them, texture is one of the most important quality attributes when it comes to snack foods (Bourne, 2002). Anton and Luciano (2002) and Harper (1981) have also reported the influence of texture and attractive appearance towards consumer acceptance with the addition of convenience and value of the snack food. The fast development of extruded snack food is because the process could improve the nutritional quality of carbohydrate-based products by diversification or fortification. Extruded products are widely acceptable by consumer because of their crispy texture and their expanded properties (Santosa *et al.*, 2008).

Many raw materials namely corn, wheat and soy bean product has long being used to produce extruded product. Corn can be considered the most widely used ingredients in making snacks (Sentosa *et al.*, 2005). Corn in the form of corn meal is widely used to make extruded food, such as ready-to-eat breakfast cereals and snacks (Singh *et al.*, 2001). The effects of extruding parameters on corn grits have been extensively studied by many researchers (Flecther *et al.*, 1985; Garber *et al.*, 1997; Hsieh *et al.*, 1990; Onwulata and Konstance, 2006; Singh *et al.*, 1998). Many literatures have successfully described the extrusion process of wheat flour (Ali *et al.*, 1996; Ainsworth *et al.*, 2005; Harper, 1979; Ilo *et al.*, 1996). There are also many studies in producing extruded food with various raw materials (Rice, wheat and potato)

and blend of different raw materials such as rice-green gram blend, barley-tomato pomace blend, barley- grape pomace blend, corn-common bean blend, chickpea-potato blend and many more (Ainswort *et al.*, 2004; Atlan *et al.*, 2007; Atlan *et al.*, 2008; Anton *et al.*, 2008; Bhattacharya, 1996; Gonzalez *et al.*, 2007; Iwe *et al.*, 2003; Sacchetti *et al.*, 2003; Martinez *et al.*, 2004; Meng *et al.*, 2009; Singh *et al.*, 2009).

There has been dearth of published literature and information regarding the effect of extrusion towards the physical properties of sweet potato and particularly its mixture with corn flour which leads to a need of further studies. Iwe (1998) have studied on the effects of extrusion cooking on mixture of full fat soy-sweet potato. He reported the varying parameters of extrusion on the expansion ratio, bulk density, water absorption and solubility indices and trypsin inhibitor of the blend of soy bean-sweet potato. There has also been lack of information on the effect of utilizing a twin screw extruder in extrusion cooking of sweet potato. Utilization of single screw extruder in extrusion cooking has been extensively studied (Santosa *et al.,* 2008). Meanwhile, twin screw extrusion cooking on corn, wheat and rice base materials has been extensively studied (Ainsworth *et al.,* 2004; Aisworth *et al.,* 2005; Bhattacharya, 1996; Hagenimana *et al.,* 2005; Ilo and Berghofer, 1998; Santosa *et al.,* 2008). Studies on extrusion of blend of soy bean- sweet potato utilizing a single screw extruder has been conducted by Iwe, (1998) Iwe *et al.* (2000), Iwe *et al.* (2001), Iwe *et al.* (2003). Hence, this study would provide extended information regarding extrusion cooking on sweet potato especially on extrusion using a twin screw extruder. The successful development of this study would introduce new utilization on the sweet potato crop. In addition, the development of sweet potato extruded snack could provide a new kind of extruded snack which has potential to replace current conventional extruded snack.

1.2 Objective

a. To study how feed moisture content and sweet potato flour ratio affects the colour, expansion ratio, bulk density, textural properties and sensory properties of extrudates.

CHAPTER 2

LITERATURE REVIEW

2.1 Sweet potato

Sweet potato (*Ipomoea batatas* [L.] Lam.), is a dicotyledonous plant which belongs to the family Convolvulaceae. Sweet potato is one of the world's most important, versatile, and relatively underexploited food crops. This sweet potato crop is originated from Central America. This crop is brought into Europe by Christopher Columbus in the 15th century. It was later brought into Philippines by Spanish explorer and into Africa, India, Indonesia and southern Asia by the Portuguese by 16th century. Sweet potato is considered as a perennial crop but can be produced as annual crop. It is an important food source in most tropical area. Sweet potato is ranked fifth most important food crops in the world and is cultivated in over 100 developing countries. They are produced on more than nine million hectares of land throughout the world with an annual production of 140 million tons with an average yield of 15,000 kg/ha (Bavec, 2000). Asia is the largest producers of sweet potato with an annual production of 114 million tons. The sweet potato that china supplied is nearly 80% of world's production, making China the largest producer of sweet potato. Half of the sweet potatoes produced in the Asia region are used for animal feed, while the remainder primarily used for human consumption, either as fresh or processed products. On the other hand, Africa region produce only about 12 million metric tons of sweet potato but most of the crop are used for human consumption (CGIAR, 2010). In Malaysia, sweet potato is the third most cultivated cash crops after cassava and corn. Sweet potato is cultivated at 1309 hectare within Malaysia and produced almost 18,228 metric ton of sweet potato per year (Jabatan Pertaninan Malaysia, 2010). The various varieties of orange fleshed sweet potatoes cultivated in Malaysia include: Gendut, Telong, Jalomas

and VitAto. The Gendut variety are recommend to be eaten freshly while Telong and Jalomas variety are suitable to be processes into flour because of their high starch content. VitAto is a new variety developed by *Institut Penyelidikan and Pembangunan Pertaninan Malaysia* (MARDI) which has higher antioxidant and vitamin A content (Jabatan Pertanian Malaysia, 2010).

Sweet potato can be considered as a small farmer's crop. They are commonly growth in tropical, sub-tropical and warmer temperate regions in the world (Woolfe, 1992). Sweet potatoes have the ability to grow well in many farming conditions. The sweet potato crop has relatively few natural enemies, thus reducing the use of pesticides. Sweet potato can be grown in poor soils with little use of fertilizer. Sweet potatoes are also easy to plant as they are sown by vine cuttings rather than through seeding. Besides that, the sweet potato crop is highly tolerant towards weeds, which enable farmers have minimal focus on this crop. The sweet potato could be harvested in three to six months time. One significant obstacles of cultivating sweet potatoes in tropical regions are pests and diseases such as the sweet potato weevil and viruses' diseases (CGIAR, 2010).

Sweet potato plant can be divided into three major parts, each of which has its own functions. Above ground, the photosynthetic canopy absorbs light energy and converts them to manageable chemical compounds (carbon compounds); the petioles and the vines then transports this energy and other resource to various parts of the plant including the roots. Below ground, the root system absorbs water and nutrient and also anchored the plant on the ground. The roots also stored excess energy which is not needed for maintenance or structural development. The energy is stored in the form of carbohydrate in large fleshy or storage roots. Each of the three major parts of the sweet potato plant has its own function and are closely related, changes in one part may result in significant changes in the other parts. It had to be stressed here that from the outset that the storage organ of the sweet potato is a root and not a tuber. Storage roots are true roots while tubers are modified stems. Thus sweet potato

has differences in both anatomy and physiology as compared to tubers. The sweet potato storage root is then undergoes enlargement or development and not "tuberisation" (Woolfe, 1992).

2.1.1 Nutritional composition of sweet potato

Sweet potato has relatively high moisture content, which resulting in relatively low dry matter content. Average dry matter content of sweep potato is approximately 30%, but this value varies significantly depending on the cultivar, location of cultivation, climate, day length, soil type, incidence of pests and disease, and cultivation practices (Bradbury and Holloway, 1988). The average composition of sweet potato dry matter is shown as in table 2.1.

Table 2.1: The approximate composition of raw sweet potato roots dry matter.

Constituent	Average Value (% dry matter)	Ranges (% dry matter)
Starch	70	30-85
Total sugars	10	5-38
Total protein (N x 6.25)	5	1.2-10
Lipid	1	1-2.5
Ash	3	0.6-4.5
Total fiber	10	?
Vitamins, organic acids and other components	<1	

Source: Woolfe, 1992

In practical, the chemical composition of dry matter sweet potato varies extremely and the concentration of each component largely depends on one or more factors explained above which influence the dry matter.

Carbohydrates made up of approximately 80-90% of sweet potato dry matter while 24-27% in fresh weight. The carbohydrates in sweet potato consist of mainly starch and sugars, with small amounts of pectins, hemicelluloses and cellulose serve as dietary fiber. Starch constitutes of 60-70% of dry matter. Like most type of starch, sweet potato starch granules are made up of amylopectin and amylose molecules, the ratio of amylopectin:amylose varies according to cultivar but generally about 3:1 or 4:1. Starch of Amylopectin is a large and highly branched polymer of alpha-1,4-linked glucose chain branching through alpha-1,6-glucosidic links. On the other hand, the amylose molecule is a smaller, unbranched, straight-chained polymer with its glucose subunit being joined by alpha-1,4- links. The major sugar in raw sweet potato consists of sucrose, fructose and glucose (Woolfe, 1992). Lipid content in the sweet potato is generally consider low and nutritional insignificant. However lipids component has been identified to caused off-odours and flavours in dehydrated sweet potatoes flakes (Woolfe, 1992). Most abundant fatty acids in sweet potato have found to be palmitic and linolic acids (Opute and Osagie, 1978; Walter *et al.,* 1971). Protein content of sweet potato is averaged about 5% (dry weight base) and 1.5% (fresh weight base). Major proteins found in sweet potato are sporamin which accounts for 80% of the total soluble proteins in sweet potato roots. Sporamin can be separated into two closely related proteins: sporamins A and B (Maeshima *et al.*, 1985).

Sweet potatoes are substantial sources of ascorbic acid (Vitamin C) and moderate sources of thiamine (B_1), riboflavin (B_2) and niacin as well as pyridoxine and its derivatives (B_6), Pantothenic acid (B_5) and folic acid. Sweet potato also contains satisfactory amount of vitamin E. The most important of sweet potatoes, is that they have significantly large quantity of carotenoids which act as precursors of vitamin A. Caroteniods are available in abundance in yellow and orange fleshed sweet potatoes especially in the form of beta-carotene (Woolfe, 1992). The beta-carotene rich orange fleshed sweet potato has been utilised throughout the world to curb vitamin A deficiency (Jala *et al.*, 1998; Low *et al.*, 2001). Besides that, sweet potatoes also

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