EFFECT OF SPRAY DRYING TEMPERATURE ON THE NUTRITIONAL COMPOSITION AND PHYSICAL PROPERTIES OF DRY MILK POWDER OF GOAT MILK

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ABSTRACT

A lab experiment was conducted at the Faculty of Sustainable Agriculture Food Bioprocessing laboratory and Final Year Project laboratory in Universiti Malaysia Sabah. This experiment was carried out to investigate the effect of spray drying temperature on dry milk powder of goat milk. The objectives of the study are to investigate the effect of spray drying temperature on the nutritional composition of dry milk powder of goat milk and to investigate the effect of spray drying temperature on the physical properties of dry milk powder of goat milk. The experimental design that used was CRD using inlet air temperature of 140°C, 160°C, 180°C (control), 200°C, and 220°C. Each has 3 replicates. The result was analyzed by a one-way analysis variance (ANOVA) using the Statistical Analysis System (SAS) version 9.4. The results showed that there are significant effects of inlet air temperature on dry milk powder in term of its protein content, fat content, moisture content and the sinkability of the milk powder. In term of fat content, T3 powder = 220°C has the highest fat content. T0 powder = 180°C has the highest protein content. Meanwhile, T1 powder = 140°C has the highest moisture content and most sinkable among all of the treatment. Overall, the control powder, T0 = 180°C, however, is still preferable as the nutritional value shown to be higher in this powder and have proper physical properties. The finding of this experiment can be modified as for the further investigation to improve the quality of milk powder in term of its nutritional value and physical properties.

KESAN SUHU SEMBURAN KERING TERHADAP KOMPOSISI NUTRISI DAN CIRI – CIRI FIZIKAL SUSU TEPUNG DARIPADA SUSU KAMBING

ABSTRAK

Satu eksperimen telah dijalankan di Makmal Biopemprosesan Makanan dan Makmal Tahun Akhir, Fakulti Pertanian Lestari, Universiti Malaysia Sabah. Eksperimen ini dijalankan untuk mengkaji kesan suhu semburan terhadap susu tepung daripada susu kambing. Objektif kajian ini adalah untuk mengkaji kesan semburan kering terhadap komposisi nutrisi susu tepung daripada susu kambing dan mengkaji kesan semburan kering terhadap ciri – ciri fizikal susu tepung daripada susu kambing. Rekabentuk eksperimen yang digunakan ialah CRD dengan menggunakan suhu udara saluran masuk iaitu 140°C, 160°C, 180°C (kawalan), 200°C, dan 220°C. Setiap satu direplikasi sebanyak 3 kali. Keputusan dianalisis secara ANOVA satu hala dengan menggunakan Sistem Analisis Statistik (SAS) versi 9.4. Keputusan yang didapati suhu semburan kering menunjukkan kesan yang signifikan terhadap kandungan protein, lemak, kelembapan dan keupayaan susu tepung untuk tenggelam. Dari segi kandungan lemak, tepung T3 = 220°C mempunyai kandungan lemak yang tertinggi. Tepung T0 = 180°C mempunyai kandungan protein tertinggi. Manakala tepung T1 = 140°C mempunyai kelembapan tertinggi dan mempunyai keupayaan tenggelam yang lebih berbanding rawatan yang lain. Keseluruhannnya, susu tepung kawalan, 180°C lebih dipilih kerana kandungan nutrisinya adalah yang tertinggi dan mempunyai ciri – ciri fizikal yang sesuai. Dapatan daripada eksperimen ini boleh diubah mengikut kesesuaian untuk penyelidikan yang lebih lanjut bagi meningkatkan kualiti susu tepung dari segi kandungan nutrisinya dan ciri – ciri fizikalnya.

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

%	Percentage
$<$	Less-than sign
$>$	Greater-than sign
±	Plus-minus sign
°C	Centigrade, Celsius
ADPI	American Dairy Product Institute
ANOVA	Analysis of Variance
AOAC	Association of Analysis Communication
Cm	Centimeter
COMTRADE	Common Format for Transient Data Exchange for Power
CRD	Complete Randomized Design
df	Degree of Freedom
F	F-ratio
FAO	Food and Agriculture Organization of the United Nations
FSA	Faculty of Sustainable Agriculture
FSSAI	Food Safety and Standards Authority of India
g	Gram
IDF	International Dairy Federation
IS	International Standard
ISI	Indian Standard Institute
ISO	International Organization for Standardization
m^3	Cubic meters
mg	Milligram
min	Minute
mL	Millimeter
MUFA	Monounsaturated Fatty Acid
N	Nitrogen
NDM	Non-fat Dairy Milk
NDRI	National Dairy Research Institute
p	Calculated Probability
PUFA	Polyunsaturated Fatty Acid
SAS	Statistical Analysis System
SEM	Standard Error Mean
SFA	Saturated Fatty Acid
Sig.	Significant value
T_{Out}	Outlet air Temperature
T_{In}	Inlet air Temperature
WHO	World Health Organization
µm	Micrometer

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Formula **Page**

3.1 Crude Protein content (Protein %) 22

$$Protein\ (\%) = Nitrogen \times 6.38$$

6.38 = Conversion factor

3.2 Fat content (Fat %) 23

$$Fat\ (\%) = \frac{\text{Weight of extracted fat}}{\text{Weight of milk}} \times 100$$

3.3 Ash content (Ash %) 23

$$\text{Ash}\ (\%) = \frac{C-A}{B-A} \times 100$$

A = Weight of empty crucible;
B = Weight of crucible and contents before drying;
C = Weight of crucible and contents after drying

3.4 Moisture content (Moisture %) 24

$$Moisture\ (\%) = \frac{100(M1-M2)}{M1-M}$$

M = Mass in grams, of the empty dish;
M1 = Initial mass in grams, of the dish and lid with the sample of milk;
M2 = Final mass in grams, of the dish and lid with material after drying

3.5 Solubility of the milk powder (Solubility %) 25

$$\text{Solubility}\ (\%) = \frac{(M4-M6)\times(M1-M2)}{(M3-M5)\times(M2-M6)} \times 100$$

M4 = Mass in grams of total solids in dish B;
M1 = Mass in grams of the liquid taken immediately after the removal of fat in dish A;
M3 = Mass in grams of total solids in dish A;
M2 = Mass in grams of the supernatant liquid taken in dish B;
M6 = Mass in grams of empty dish B with lid;
M5 = Mass in grams of empty dish A with lid

CHAPTER 1

INTRODUCTION

1.1 Background

Milk is a nutritionally complete food and the consumption is generally high in developed countries, low in developing ones and particularly low in tropics and subtropical climates. James (2015) stated that the milk consumption in developed countries is 100 kilograms per person per year, 70 kilogram in Europe and less than 40 kg per person in developing countries. However, population growth and changing of consumer habits have resulted in increasing demand for milk and milk products. Malaysia ranked among the highest per capita consumption in the Southeast Asian region at 36.2 kilogram per person per year in 2009 (Khor *et al.*, 2014). However the shelf-life of raw milk is limited and highly perishable due to its high water content. Therefore, converting milk into milk powder not only increases its shelf life but also can be stored without substantial loss of quality (Sharma *et al.*, 2012). Sun (2009) stated that liquid milk was dehydrated through several drying process until it is a powder. The water content in milk powder is about 5% (Suharyanto, 2009).

There are several advantages of dried milk products over fresh milk products. These include lower mass and volume properties of dried milk powder which means that they may be stored in a smaller storage space without complex storage requirements, and may be transported easily at lower cost (Caric, 1987). Sun (2009) stated that milk powder has a far longer shelf-life than liquid milk due to its lower water content. As the demand for milk is rapidly increasing especially in developing countries, drying of milk can balance the supply of milk and can be stored for longer period forming a stable food reserve for future use (Caric, 1987). Harrison (2010) stated that the milk is reconstituted in recombining dairy plants and is used to combat malnutrition in poorer country. It is important to process the product under stringent hygiene environments while retaining all the desirable properties of the milk (Sun, 2009). Thus, further research has to be done on increasing quality and quantity of milk powder, as well as, an economical market value for milk powder.

Dry milk powder has three different types. There are whole milk powder type, skim milk powder or non-fat dry milk and buttermilk powder. Whole milk powder contain between 26% and 40% milk fat with 5% moisture, skim milk powder contain <1.5% milk fat and <5% moisture while buttermilk powder has 4.5% milk fat and <5% moisture (FAO and WHO, 2011). Milk powder manufacture involves simple process by which water is gently removed under stringent hygiene conditions and retaining all its desirable properties of milk such as flavour, colour, solubility and nutritional value (Sun, 2009). Gaiani *et al.* (2010) stated that spray drying is the most widely applied technology to dry aqueous or organic solutions, in industrial chemistry and food industry including milk powder manufacturing. Other alternative besides spray drying are drum-drying and freeze drying (Onwulata, 2005).

Spray drying is a technology of transformation of liquid food or products into powder form and used more widely than any other drying method. However, a method of removing as much moisture as possible prior to spray drying is required to avoid unacceptable powder properties and powder losses (Early, 1998). Separation or standardization is the first conventional process for the production of milk powder by which the raw milk is pasteurized and separated into cream and skim milk (Sun, 2009).

Saraswathi (2015) stated that the principle of spray drying involves moisture evaporation from an atomized feed by mixing the spray and drying medium which is typically air. She also noted that the drying proceeds until reaching the desired moisture content and the product is then separated from air. The spray-dried powders physicochemical properties are influenced by the process variable such as feed viscosity, flow rate, pressure and temperature of drying air as well as the type of atomizer (Tee *et al.*, 2012). Hence, it is crucial to optimize the spray drying combining system since it will influence the product quality and yield.

Outlet air temperature is the dominating factor in controlling drying rate and most commonly used as the operational variable for controlling powder moisture (Masters, 1985). Several properties of powder, such as physicochemical, electrical conductivity, total dissolved solid, particle size and diameter depend on the operating variable (Chegini *et al.*, 2014). For a proper study of spray drying outlet air temperatures variable, nozzle atomizers must run at constant pressure to avoid errors in data collection.

Microencapsulation process also applied in spray drying. Microencapsulation is the process of enclosing the active agent in particle or droplet using a coating or embedded in homogeneous or heterogeneous matrix at micro to nano scale. Encapsulation coat and protect the core against stresses encountered during processing and prevent degradation during storage as well as reduce the stickiness during processing (Augustin *et al.*, 2009). Augustin *et al.* (2009) also noted that encapsulation isolate the core from environment until external stimulus triggers for its response of release. Most microcapsules are simple spheres and have diameters between a few micrometers and a few millimeters depending on the material used for coating and methods of its preparation (Gharsallaoui *et al.*, 2007). In this study, maltodextrin is used as microencapsulation agent since it is widely used in processes of spray drying and given its high values of solubility in water as well as prevents the loss of flavor during spray drying process (Desai and Park, 2005; Ersus and Yurdagel, 2007).

1.2 Justification

Malaysia relies heavily on imports of dairy products mainly from New Zealand, United States and Australia to satisfy its domestic demands (COMTRADE, 2015). The rising population along with the awareness on the nutritional goodness of dairy products has contributed to the increase in demand for dairy products in Malaysia. According to Suntharalingam and Ahmad (2015), the milk production has increased over the past four decades but still unable to meet the dairy demand of its population. Since the milk production in Malaysia is very limited, it is important to reduce the loss during milk powder production due to its quality failure. Therefore, effective process control is essential if dairy milk powder product is to be manufactured safely, compliance with regulatory requirement and acceptable product quality as well as low manufacturing costs.

In this study, optimum operational variable in milk production can be applied by the local dry milk powder producer to maintain the safe milk powder production and retaining the desired quality at consistent rate as well as reducing the loss due to quality failure. Besides that, the stereotype of local dry milk powder which is thought as low in quality will be reduced. Thus, conducting a research on investigating the effect of spray-drying temperature on dry milk powder production will be really meaningful in prolonged milk shelf life in powder form and to the health conscious community.

1.3 Objectives

The objectives of this study were:

i. To investigate the effect of spray drying temperature on the nutritional composition of dry milk powder of goat milk.

ii. To investigate the effect of spray drying temperature on the physical characteristics of dry milk powder of goat milk.

1.4 Hypothesis

Hypothesis for objective is as follow:

i. H_o: Spray drying temperature would have no significant effects on the nutritional composition of dry milk powder.

H_a: Spray drying temperature would have significant effects on at least one of the nutritional composition of dry milk powder.

ii. H_o: Spray drying temperature would have no significant effects on the physical characteristics of dry milk powder.

H_a: Spray drying temperature would have significant effects on at least one of the physical characteristics of dry milk powder.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Goat Milk

Goat (*Capra aegagrus hircus*) serves as the providers of meat while milk is a direct product of goat. Goat meat or often called as chevon accounting for 4.6% of the world meat intake in 2012 (FAO, 2015). Apparently, worldwide milk consumption is 65% from goat's milk (Cooke, 2010). Milk of goat is differed from cow milk in term of having therapeutic values, better digestibility and less allergenic (Jenness, 1980). It is also considered to be a very complex balanced food (Bartošovičová, 2011). In Asia, there are only 13 breeds are identifiable dairy goat breeds and these breeds are also produce low-medium milk (Devendra, 2007). He also stated that since goat milk has a significant niche market in Malaysia, there has been a dramatic development of dairy goat farming in this country but still rely on large importation of dairy goats from various countries. Since the liquid raw material is perishable and not everyone have access to goat farm, there are several methods used to preserve the milk which includes the use of heat, freezing, use of chemical preservative and most commonly used in dairy industry is converting the liquid raw material to milk powder (Fraizeir and Westhoff, 1981).

2.1.1 Composition of Goat Milk

According to Anifantakis *et al.* (1980), the composition of goat milk is different from a cow, sheep and human milk but also vary with diet, breed, individuals, parity, season, feeding management, environmental conditions, locality, stage of lactation, and health status of the udder. Overall, the major composition of milk divided into five categories, namely carbohydrates, proteins, fats, vitamins and minerals (Bartošovičová, 2011). Table 2.1 described the average composition of basic nutrients in goat, sheep, cow and human milk as reported by Filiz (2013).

Table 2.1 Average compositions of basic nutrients in goat, sheep, cow and human milk

Composition	Goat	Sheep	Cow	Human
Fat (%)	3.8	7.9	3.6	4.0
Solids-non-fat (%)	8.9	12.0	9.0	8.9
Lactose (%)	4.1	4.9	4.7	6.9
Protein (%)	3.4	6.2	3.2	1.2
Casein (%)	2.4	4.2	2.6	0.4
Albumin, globulin (%)	0.6	1.0	0.6	0.7
Non-protein N (%)	0.4	0.8	0.2	0.5
Ash (%)	0.8	0.9	0.7	0.3
Calories/100 ml	70	105	69	68

Source: Filiz (2013)

Some particular properties of goat milk confer technological advantages in comparison to cow's milk such as lower amounts of asl-casein which result in softer gel products, a smaller size of fat globules , resulting in smoother texture in derived product, a lower viscosity and a higher water holding capacity (Haenlein, 2004).

The nutritional advantage of goat milk compared to cow milk come from the lipids, or more precisely the fatty acids within the lipids (Babayan, 1981; Park, 1994; Haenlein, 2004). Goat milk has higher proportion of caprylic, capric and caproic acids which lend characteristics flavor and odor of goat milk (Ha and Lindsay, 1993; Alonso et al., 1999). Holland *et al.* (1989) claimed that goat milk has the lowest cholesterol content among the 3 species and this described in Table 2.2.

Table 2.2 Cholesterol and fatty acid composition of milk from different species

Milk	Fatty Acids (g/100g) SFA	MUFA	PUFA	Cholesterol(mg/100g)
Cow				
Whole	2.4	1.1	0.1	14
Skim	0.1	-	-	2
Dried whole	16.5	7.6	0.8	120
Goat	2.3	0.8	0.1	10
Sheep	3.8	1.5	0.3	11

Source: Holland *et al.* (1989)

According to Posati and Orr (1976), 6 out of 10 essential amino acids are higher in goat milk compared to cow milk. Table 2.3 compared the average essential amino acids composition in proteins of goat and cow milk (Posati and Orr 1976).

Table 2.3 Average essential amino acid composition (g/100g milk) in protein of goat and cow milk

Essential amino acids	Goat milk	Cow milk	Difference (%) for goat milk
Tryptophan	0.044	0.046	-
Threonine	0.163	0.149	+9
Isoleucine	0.207	0.199	+4
Leucine	0.314	0.322	-
Lysine	0.290	0.261	+11
Methionine	0.080	0.083	-
Cystine	0.046	0.030	+53
Phenylalanine	0.155	0.159	-
Tyrosine	0.179	0.159	+13
Valine	0.240	0.220	+9

Source: Posati and Orr (1976)

Barrionuevo *et al.* (2002) did a research on a rat which had a mal-absorption syndromes showed improvement in intestinal absorption of copper after fed with milk goat and this attributed by higher contents of cysteine which derived from cysteine in goat milk (83 mg/ 100 g) compared to cow milk (28 mg/100 g). In addition, goat milk consumption meet equally or exceeded by a 0.51 of adult daily dietary nutrient recommendations for essential amino acid (NRC, 1968).

2.2 Properties of Milk Powder

Several properties of powdered products, for the most part of a physical nature, affect the quality of the powder and powders in the market must meet the general standard specification of trade which is described by ADPI (2002) in Table 2.4.

Table 2.4: Specification for dry milk products

Product	ADPI[a]	Codex Alimentarius
Skim Milk Powder		
Fat	Max. 1.25%	Max. 1.5%
Solubility Index	Max. 1.2 ml	Max. 1.0 ml
Bacterial Estimate[c]	Max. 10,000/g	-
Scorched particles	Max. Disc B (15.0 mg)	Max. Disc B
Full-cream Milk Powder		
Fat	Min. 26%, Max.40%	Min. 26%, Max. 42%
Water	Max. 4.5%[d]	Max. 5.0%
Protein		Min. 34%[e]
Titratable acidity	Max. 0.15%	Max. 18[b]
Solubility Index	Max. 1.0 ml	Max. 1.0 ml
Bacterial estimate	Max. 10,000/g	-
Scorched particles	Max. Disc B (15.0 mg)	Max. Disc B

[a]ADPI (2002) specifications for Extra Grade
[b]As ml 0.1 N NaOH/10g solids-not-fat
[c]With coliforms not greater than 10/g
[d]As determined by weight of moisture on a milk solids-not-fat basis
[e]As a proportion of milk solids-not-fat

Source: ADPI (2002)

2.2.1 Physical Characteristics of Powders

The term of bulk density is a measure of the powder weight that can be contained in a set or known volume and also referred to as packing density expressed in g/cm^3, kg/m^3, or g/100ml (Pisecky, 1997). He also stated that the bulk density has an influence on powder functionality including wettability, dispersibility, instantizing and also is a consideration for packaging. According to Lovell (1980) and Peleg (1983), the bulk density of milk powders is affected by processing conditions, in particular, as the total solids increases, bulk density is also increasing.

Powder flowability refers to the ease of powder particles move with respect to each other which is resistance to flow (Royal and Carson, 1991; Kim *et al.*, 2005). Ilari (2002) stated that in the dairy industry, flowability is decisive for air transportation, bin filling and emptying, bag filling and storage, storage in silos and dosing calculated quantities or selecting parameters for conditioning and mixing of powders. According to Prescott and Barnum (2000), it is a determining factor for the machinery designing to ensure proper flow of powder and to prevent the formation of clogs. They also claimed that good flow properties of powder are those with large agglomerates and few fines.

Wettability is a measure of the powder ability to absorb water on the surface, to be wetted, and to penetrate the surface of still water and it defines the powder potential to wet and absorb water at a given temperature (Sharma *et al.*, 2012). They also claimed that the lower the contact angle, the greater the wetting. Surface coverage with hygroscopic components such as lactose yields better properties of wetting because of the small contact angle (Fäldt and Bergenståhl, 1996; Kim *et al.*, 2005). Kim *et al.* (2005) stated that wettability also determined by the temperature of the water used and surface composition of powders. A common method for measuring wettability consists of systematically placing a weighed amount of powder on the known volume surface of the water at a set temperature and then measuring the time taken for all of the powder to disappear below the surface of water (Pisecky, 1997).

Other properties of milk powders are sinkability which is defined as the ability of powder practices to overcome the water surface tension and sink into the water and it is expressed as mg of powder that sink/min/cm^2 of surface area (Schober and Fitzpatrick, 2005). Schober and Fitzpatrick (2005) also described that the sinkability may be measured by recording the time taken for the disappearance of powder from the water surface after adding a portion of milk powder to water and stirred with an impeller under constant conditions.

Dispersibility is another important feature of milk powders and it can be defined as the ability of a powder to separate into the individual particle when dispersed in water with gentle mixing (Tamime, 2009). Tuohy (1989) claimed that very dispersible powders typically exhibit great wettability and are agglomerated with the absence of fine particles.

2.2.2 Physical Functionality of Powders

Solubility is a prerequisite for most other functional attributes because poorly soluble powders can cause difficulties in processing and can result in economic losses (Sharma, *et* al., 2012). According to Singh and Newstead (1992), there are five major factors which directly influence the solubility of milk powders; (1) the presence of lactic acid in milk, (2) the preheat treatment of milk, (3) type of spray-drying, (4) a heat stabilizing agent added to milk prior to manufacture, and (5) levels of salt ions in the protein of milk powder. The most critical factor controlling the solubility of powders is the temperature of the particle during drying stage when the moisture content is between 10% and 30% (Straatsma *et al.*, 1999).They also stated that the insoluble material is usually made up of denatured protein (typically β-lactoglobulin) followed by its aggregation with casein.

Mainly, the heat stability of milk is a function of its milk protein stability and may be influenced by protein content and thus, standardization of protein can be used to achieve more consistent protein content in dairy products as well as improve heat stability (Singh, 2004). Sikand *et al.* (2010) claimed that heat stability is also influenced by the type of NDM powder (low- or medium- heat powder) and standardization material (edible lactose powder or permeate powder). Another factor that affects the heat stability of milk powder is heat temperature applied during powder manufacture by which high preheat treatment is needed to ensure but is not a sufficient guarantee for heat stability (Newstead, 1977; Madkor and Fox, 1990).

Milk powders that offer good foaming capabilities and good emulsifying are required for some applications (Augustin and Clarke, 2008). According to Philips *et al.* (1987), the foaming stability of milk powder refers to the relative ability of the foam to withstand spontaneous breakdown or collapse from external causes. Both caseins and whey proteins contribute to the foaming properties of milk (Dickinson *et al.*, 1989). Foaming capacities can be measured by using domestic mixers with milk solutions at set temperatures and times and the resultant foam generated are measured (Philips *et al.*, 1987).

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