UNIVERSITI PUTRA MALAYSIA

INFLUENCE OF DIFFERENT FAT REPLACERS AND DRYING TECHNIQUES ON PHYSICOCHEMICAL CHARACTERISTICS AND SENSORY ATTRIBUTES OF REGULAR AND INSTANT REDUCED-FAT COFFEE CREAMER

SIMIN HEDAYATNIA

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By

SIMIN HEDAYATNIA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirement for the Degree of Master of Science

January 2015

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DEDICATION

This thesis is dedicated to my beloved father and mother who are always giving me their unlimited support, love, patience and understanding.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement of the degree of Master of Science

INFLUENCE OF DIFFERENT FAT REPLACERS AND DRYING TECHNIQUES ON PHYSICOCHEMICAL CHARACTERISTICS AND SENSORY ATTRIBUTES OF REGULAR AND INSTANT REDUCED-FAT COFFEE CREAMER

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Chairman : Assoc. Prof. Seyed Hamed Mirhosseini

Faculty : Food Science and Technology

Coffee is one of the most popular soft drinks all around the world. Most of coffee drinkers prefer to add creamer and/or whitener to their coffee before sunsumption. Coffee creamers usually contains high amount of the saturated fat (15-40%). Therefore, the frequent consumption of the whitened coffee can induce many health issues (e.g. cardiovascular and chronic diseases) for coffee drinkers. In recent years, the demand for low- and reduced-fat products has been extensively increased. The aim of the present study was to formulate and characterize the reduced-fat coffee creamer with the most desirable characteristics comparable with commercial creamers.

The main objective of the present study was to investigate the effects of different type and content of fat replacer (i.e. inulin, 0, 2.5, 5 and 7.5%; maltodextrin, 0, 15, 20 and 25%, w/w) as well as different drying techniques (i.e. spray drying, drum drying and fluidized-bed drying) on physicochemical properties, microstructures, and sensory attributes of the regular-and instant reduced-fat creamers. The regular coffee creamers were produced by a single-stage drying (either spray drying or drum drying only); while the instant reduced-fat coffee creamers were produced by a double-stage drying (i.e. spray drying or drum drying along with fluidized-bed drying). Physicochemical properties of all formulated creamers were compared with the control (as a negative control) and commercial creamers (as a positive control).

The current study revealed that the physicochemical characteristics, microstructures, and sensory attributes of both regular-and instant reduced-fat creamers were significantly ($p \leq 0.05$) influenced by both fat replacers and drying techniques. Moisture content, water activity of regular-and instant creamers were notably decreased by increasing the concentration of maltodextrin and inulin. This could be due to significant ($p \leq 0.05$) increase in solid content of samples. The bulk density of regular-and instant creamers was dropped by increasing the content of target fat replacers and enlarging the particle size. The current study revealed that the

wettability, solubility, viscosity and glass transition temperature of the formulated creamer were significantly ($p \leq 0.05$) improved as the contents of inulin or maltodextrin in the creamer formulation were increased.

The present study revealed that spray dried reduced-fat creamer had smaller spherical or oval shape particles than the drum dried creamers; while drum dried samples had much bigger particles with irregular shape. In this study, the drum-dried creamers had darker colour (or lower lightness) than the spray-dried samples. This might be because of its higher drying temperature and longer residence time. The drum-dried creamers with markedly bigger particle size and lower moisture content had considerably lower bulk density than the spray-dried creamer.

The current study revealed that the instant reduced-fat creamer had higher glass transition temperature than the regular reduced-fat creamer. This could be explained by the fact that the instant reduced-fat creamer had markedly lower moisture content than the regular creamer because the application of fluidized-bed drying led to decrease the moisture content, water activity, bulk density and stickiness. The agglomeration induced by fluidized bed drying significantly increased the reconstitution properties (wattability and solubility), viscosity and glass transition temperature of the reduced fat creamer. The morphology analysis revealed that agglomeration caused by fluidized-bed drying resulted in bigger particles with more porous structure than the regular creamer. Finally, the current study revealed that the instant spray-dried creamer (containing 25% maltodextrin and 7.5% inulin) had better quality comparable with commercial creamer than the instant drum-dried sample with similar formulation. The current study showed that instant spray-and drum dried reduced-fat creamers containing high amounts of maltodextrin (25%, w/w) and inulin (7.5%, w/w) had the most desirable characteristics among all formulated creamers comparable with the commercial creamer.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebegai memenuhi keperluan untuk ijazah Master Sains

KESAN PELBAGAI JENIS LEMAK PEGANTI DAN TEKNIK PENGERINGAN KE ATAS SIFAT FIZIOKIMIA DAN DERIA RASA KOPI KRIMER KURANG LEMAK BIASA DAN SEGERA

Oleh

SIMIN HEDAYATNIA

Januari 2015

Pengerusi : Profesor Madya. Seyed Hamed Mirhosseini

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Kopi merupakan salah satu minuman paling digemari di seluruh dunia. Majoriti peminum kopi biasanya memilih untuk menambah krimer dan/atau pemutih di dalam kopi. Namun begitu, kopi krimmer kebiasaanya mengandungi kandungan lemak tepu yang tinggi iaitu 15-40%. Pengambilan yang kerap akan menyebabkan pelbagai isu kesihatan akan timbul seperti penyakit kardiovaskular dan penyakit kronik. Justeru itu, permintaan terhadap produk kurang lemak semakin meningkat sejak kebelakangan ini. Kajian ini bertujuan untuk menghasilkan formulasi dan ciri-ciri kopi krimmer rendah lemak yang paling standing dengan krimmer komersial. Objektif utama kajian ini adalah untuk mengkaji kesan pelbagai jenis dan kandungan pengganti lemak (seperti inulin, 0, 2.5, 5 and 7.5%; maltodextrin, 0, 15, 20 dan 25%, w/w) selain penggunaan teknik pengeringan (seperti pengeringan semburan pengeringan dram dan pengeringan terbendalir katil) ke atas sifat fiziokimia, struktur mikro dan deria rasa krimer rendah lemak biasa dan segera. Krimer kopi yang biasa dihasilkan dengan menggunakan pengeringan peringkat tunggal (sama ada pengeringan semburan atau pengeringan dram), manakala kopi krimer segera dihasilkan menggunakan pengeringan peringkat berganda (seperti pengeringan semburan atau pengeringan dram bersama terbendalir katil). Sifat fiziokimia semua krimer berfomulasi akan dibandingkan dengan krimer kawalan (sebagai kawalan negatif) dan krimer komersial (sebagai kawalan positif).

Kajian ini telah menunjukkan ciri fiziokimia, struktur mikro dan deria rasa kedua-dua krimer biasa dan segera menghasilkan perbezaan yang ketara setelah teknik pengeringan digunakan ($p \leq 0.05$). Kandungan kelembapan, iaitu aktiviti air krimer biasa dan segera menunjukan penurunan dengan peningkatan kepekatan maltodekstrin dan inulin. Ini mungkin disebabkan perbezaan yang ketara ($p \leq 0.05$) meningkat dalam kandungan sampel pepejal. Ketumpatan pukal krimer biasa dan segera menurun dengan peningkatan sasaran kandungan peganti lemak dan pembesaran saiz zarah. Kajian ini juga menunjukkan bahawa kebolehbasahan, kelarutan, kelikatan dan suhu peralihan kaca krimer berfomulasi menunjukkan

perbezaan yang ketara ($p \leq 0.05$) meningkat setelah kandungan inulin atau maltodekstrin ditingkatkan.

Kajian ini juga menunjukkan bahawa pengeringan semburan krimer kurang lemak mempunyai zarah berbentuk sfera atau bujur yang lebih kecil berbanding penggunaan pengeringan dram yang mempunyai zarah lebih besar dengan bentuk yang tidak teratur. Dalam kajian ini, krimer dari pengeringan dram mempunyai warna lebih gelap (atau kecerahan yang lebih rendah) daripada sampel krimer daripada pengeringan semburan. Ini mungkin kerana suhu pengeringan yang lebih tinggi dan masa pengeringan lama. Krimer daripada pengeringan dram dengan saiz zarah yang lebih besar dan kandungan lembapan yang lebih rendah mempunyai ketumpatan pukal lebih rendah daripada krimer pengeringan semburan.

Kajian ini juga menunjukkan krimer rendah lemak mempunyai suhu peralihan kaca yang lebih tinggi (T_g) daripada krimer yang biasa. Ini dapat dijelaskan oleh fakta yang mengatakan bahawa krimer segera rendah lemak mempunyai kandungan kelembapan yang rendah berbanding krimer biasa kerana penggunaan pengeringan terbendalir katil mengurangkan kandungan kelembapan, aktiviti air, ketumpatan pukal dan kelekitan. Aglomerasi disebabkan oleh pengeringan terbendalir katil meningkat dengan ketara sifat pelarut (kebolehbasahan dan kelarutan), kelikatan dan suhu peralihan kaca krimer kurang lemak. Analisis morfologi mendedahkan aglomerasi disebabkan oleh pengeringan terbendalir katil menghasilkan zarah yang lebih besar dengan struktur lebih poros daripada krimer biasa.

Kesimpulannya, kajian ini menunjukkan bahawa krimer segera daripada pengeringan semburan (yang mengandungi 25% maltodekstrin dan 7.5% inulin) mempunyai kualiti yang lebih baik setanding dengan krimer komersial daripada kopi segera daripada pengeringan dram dengan formulasi yang sama. Kajian ini juga menunjukkan bahawa krimer segera pengeringan semburan dan krimer rendah lemak pengeringan dram yang mengandungi jumlah maltodekstrin yang tinggi (25%, w / w) dan inulin (7.5%, w / w) mempunyai ciri-ciri yang paling dikehendaki di kalangan semua Krimer berfomulasi setanding dengan krimer komersial.

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This Thesis was submitted to the Senate of University Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the supervisory committee were as follows:

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
DE	Dextrose equivalent
DPHP	Di-potassium hydrogen phosphate
e.g	Exempli gratia
etc	Et cetera
et al	Et alibi
g	Gram
pH	Hydrogen ion exponent
IN	Inulin
Kcal/g	Kilocalories per gram
Kg	Kilogram
Kj/g	kilojoules per gram
Kpa	kilopascals
kWh.tonne-1	kilowatt hour per tonne
MA	Maltodextrin
µL	Microliter
mL	Milliliter
mm	Millimeter
mg	Milligram
mL/min	Milliliters per minute
min	Minute
MPa	Mega Pascal
rpm	Revolution per minute
DRFC	Drum-dried reduced-fat creamer
SRFC	Spray-dried reduced-fat creamer
RS	Rotation speed
SEM	Scanning electron microscopy
SMP	Skim-milk powder
SP	Steam pressure
T	Temperature
h	Time (Hour)
s	Time (Second)
US	United States
$D_{3,4}$	Volume-weighted mean particle size, µm
H_2O	Water
w/w	Weight/weight
WPNI	Whey Protein Nitrogen Index
°C	Degree centigrade
≤	Equal or less
%	Percentage

CHAPTER 1

INTRODUCTION

The recent changes in the lifestyles of numerous people worldwide have led to an increase in demand for convenient health food products, along with healthier foods in general, such as food products containing low-fat content and high fibre level, which produce lower energy level in the human's body (Nishinari, 2009). The recommended daily intakes of total fibre for adults are 38 and 35 g for men and women, respectively (Trumbo et al., 2002). Fat is the most concentrated source of energy in the diet program that is providing 9 kcal/g energy as compared to 4 kcal/g for proteins and carbohydrates (American Heart Association, 1996). However, consumers prefer to consume foods with minimal or reduced-fat irrespective of the food taste. As shown by the Calorie Control Council (CCC, 1996), 88% of American adults prefer to consume the low- or reduced-fat or even fat-free foods and beverages because high fat daily intake is always associated with high risk for the obesity, cancer, chronic and cardiovascular diseases. Table 1.1 summarized some of the health issues that describing the consumer preferences for low-fat products. One of the most common strategies for low fat products is to use fat replacers to compensate for the shortcomings in the sensory attributes and textural properties of the product (Sandrou and Arvantoyannis, 2000). However, this strategy does not guarantee the textural properties (such as creaminess) and consumer acceptability (Szczesniak, 2002). Food scientists have conducted extensive research to develop an "ideal fat replacer" that could provide similar taste and functional properties comparable to conventional fat, but without inducing any negative side effects on the human health (Akoh, 1998).

Table 1.1. Main consumer preference to have reduced-fat products

Why people use reduced-fat food products?	Percentages%
To stay in better overall health	77
To eat or drink healthier food and beverages	71
To reduce fat intake	68
To reduce cholesterol	61
To maintain current weight	57
To reduce calories	56
To maintain an attractive physical appearance	52
To reduce weight	43
For refreshment or taste	39
To help with a medical condition	31

Source: Calorie Control Council (CCC) 1996, natural survey

Coffee creamer, also known as "coffee whitener" or "coffee sweetener" are liquid or granular substances intended to substitute for milk or cream as an additive to coffee or other beverages. Coffee additives are dried milk concentrates, evaporated

milk, coffee cream, liquid milk, and coffee whiteners or creamer (Kelly et al., 1999). A desired or preferred coffee creamer is supposed to have certain characteristics in terms of solubility, stability, whitening ability and viscosity (Golde and Schmidt, 2005; Tuot et al., 2014). Coffee creamer should remain physically stable during storage and its viscosity should be constant over the time of storage. Coffee creamer should be dissolved rapidly in the hot water without separation of its components. In addition, it should provide a good whitening effect after adding to hot coffee or similar hot beverages (Oldfield and Singh, 2005).

One of the main health issues for coffee drinkers is the presence of high percentage of fat in creamer formulation. In this regard, the reduced-fat creamer can be alternatively produced by the partial replacement of fat portion with fat replacer components (i.e. fat replacers such as maltodextrin and inulin). Maltodextrin is one of the most popular polysaccharide-based fat replacers. It has many industrial applications based on the degree of starch hydrolysis.Furthermore, it is a white powder with low bulk density and soluble in water which is widely used as a texture modifier, gelling agent, fat replacer, volume enhancer, and encapsulation agent (Kiessling and Zeller, 2005). Inulin is another type of water soluble carbohydrate with a neutral taste and minimal side effects on organoleptic attributes of the food product (El-Nagar et al., 2002). In the current study, the effects of different concentrations of maltodextrin and inulin on physiochemical characteristics and organoleptic attributes of the regular-and instant reduced-fat creamers were investigated.

The characteristics of coffee creamer are also highly influenced by the processing conditions. Drying is the most important processing step as it has different effect on the characteristics of powder products. Spray drying is one of the most common techniques applied for different food products (Chegini and Ghobadian, 2005; Chavez and Ledeboer, 2007) such as, creamer powder (Kiessling and Zeller, 2005; Beeson and Erickson, 2001), milk powder (Yazdanpanah and Langrish, 2011) and yogurt (Koc et al., 2010). However, it has several technical disadvantages such as high energy consumption, thermal degradation and production of the amorphous particles (White and Cakebread, 1966). Drum-drying is another drying technique thatis widely used in bakery goods, beverages, cereal and dairy foods (Pua et al., 2010). The main advantages of drum drying are high drying rate and low production cost compared to other drying techniques (Vega et al., 2001). Moreover, further agglomeration is highly recommended to improve the quality and reconstitution properties of spray-and drum dried powders. In this regards, fluidized-bed drying is widely used for agglomeration purpose after drying process especially for spray drying. This may be possibly lead to induce further crystallization (Yazdanpanah and Lngrish, 2011). The main research questions were as follows:

- Whether different drying techniques and conditions can significantly affect the physicochemical characteristics and overall acceptability of the regular-and instant reduced-fat creamer?

- Is there any significant different among all formulated creamers before and after fluidized-bed drying? Or is there any significant difference between physicochemical characteristics and overall acceptability of the regular-and instant reduced-fat creamers?

- Which one of fat replacers and drying techniques can provide creamer with more desirable characteristics and overall acceptability?

- Is there any significant difference between commercial creamers and newly formulated reduced-fat creamer in terms of overall quality and acceptability?

In this study, the effects of different drying techniques (i.e. drum-drying, spray-drying and fluidized-bed drying) and type and concentration of the fat replacers (maltodextrin and inulin) on physicochemical characteristics, functional properties and overall acceptability of the regular-and instant reduced-fat creamer were all investigated. The efficiency of different drying techniques and creamer composition were determined by assessing moisture content, water activity, bulk density, morphology structure, particle size distribution, wettability, solubility, viscosity, and glass transition temperature, colour intensity, and sensory attributes of various formulated creamers. The main goal of the present work was to produce the regular-and instant reduced-fat creamers with desirable physicochemical and functional characteristics comparable with commercial coffee creamers. In the current study, the specific objectives were as follows:

- To investigate the effect of type and content of fat replacers on physicochemical characteristics and overall acceptibility of regular-and instant reduced-fat coffee creamer.

- To evaluate the effect of drying techniques on physicochemical characteristics and overall acceptibility of regular-and instant reduced-fat coffee creamer.

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