



UNIVERSITI PUTRA MALAYSIA

***CHARACTERIZATION OF PROTEIN POWDER FROM MONOPTERUS
ALBUS (SWAMP EEL)***

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ABSTRACT

Monopterus Albus commonly known as Asian swamp eel or 'belut sawah' are widespread type of eel found in Malaysia. This eel is a high-protein source of food (50.07 to 74.31%), contain healthy nutrients is very good for human body for tissue repairing as well as improve immune system. This study is focused on the effect of maltodextrin on nutritional value, physiochemical and functional properties of eel protein powder. Maltodextrin at different concentration which were 25 and 100% was added to the feed and then spray dried at 160°C inlet air temperature. The amount of protein, moisture, fat and carbohydrate in the protein powder at maltodextrin concentration of 25 and 100% were 4.4 and 0.7, 8.6 and 8.5, 0.2 and 0.1, 86.4 and 90.6 (%) respectively. The vitamin C and the yield of protein powder were increased with the increasing of maltodextrin. Protein powder with 25% maltodextrin was further analysed for the amino acid and fatty acid profile. The total amino acid is 15.14 mg/g extract with the highest for essential and non-essential amino acid were phenylalanine (2.08 mg/g) and glutamic acid (1.74 mg/g) respectively. Meanwhile, palmitic acid was recorded as the major fatty acid. The lightness and tap density of powders increased with increasing of maltodextrin while the pH remains constant at both concentrations. The spray-dried eel powder had the higher water binding capacity and protein solubility at 100% maltodextrin which were 21.2 and 27.14%. Meanwhile, the foaming capacity of the spray-dried eel protein powder with maltodextrin at 25% was higher (126%) than 100% (108%). From the study, the concentration of 25% maltodextrin is more favourable to produce the eel protein powders from *Monopterus Albus* by using the spray-drying process at inlet temperature of 160°C. The powder offers good source of high-quality amino acids and both MUFA and PUFA

content. This study indicated opportunities to produce value-added products from eel farm and processing the by-products such as food enhancer, health supplement and as ingredients for topical medication. Future study should be done especially on the effect of drying method or utilization of other additives in the feed during spray drying on the quality of the powder.



ABSTRAK

Belut sawah, juga dikenali sebagai *Monopterus Albus* atau 'Asian swamp eel' adalah sejenis belut yang banyak terdapat di Malaysia. Belut ini merupakan sumber makanan berprotein tinggi (50.07 hingga 74.31%), mengandungi nutrien yang sihat yang sangat baik untuk tubuh manusia untuk membaiki tisu serta meningkatkan sistem imun. Kajian ini tertumpu kepada kesan maltodekstrin terhadap kandungan nutrisi, sifat fisiokimia dan fungsi serbuk protein belut. Maltodekstrin pada kepekatan berbeza iaitu 25 dan 100% telah ditambah ke dalam larutan protein larut belut dan kemudian dikeringkan pada suhu udara masuk 160°C dengan menggunakan pengering semburan. Jumlah protein, lembapan, lemak dan karbohidrat dalam serbuk protein pada kepekatan maltodekstrin sebanyak 25 dan 100% masing-masing ialah 4.4 dan 0.7, 8.6 dan 8.5, 0.2 dan 0.1, 86.4 dan 90.6 (%). Vitamin C dan hasil serbuk protein meningkat dengan peningkatan maltodekstrin. Serbuk protein dengan 25% maltodekstrin dianalisis selanjutnya untuk profil asid amino dan asid lemak. Jumlah asid amino ialah 15.14 mg/g ekstrak dengan yang tertinggi bagi asid amino perlu dan tidak perlu ialah fenilalanin (2.08 mg/g) dan asid glutamat (1.74 mg/g) masing-masing. Sementara itu, asid palmitik direkodkan sebagai asid lemak utama. Kecerahan dan ketumpatan pili serbuk meningkat dengan peningkatan maltodekstrin manakala pH kekal malar pada kedua-dua kepekatan. Serbuk belut mempunyai kapasiti mengikat air dan keterlarutan protein yang lebih tinggi pada 100% maltodekstrin iaitu 21.2 dan 27.14%. Sementara itu, kapasiti pembuih serbuk protein belut dengan maltodekstrin pada 25% adalah lebih tinggi (126%) daripada 100% (108%). Daripada kajian, kepekatan 25% maltodekstrin adalah lebih baik untuk menghasilkan serbuk protein belut daripada *Monopterus Albus* dengan menggunakan proses pengeringan semburan pada suhu masuk 160°C. Serbuk ini menawarkan sumber

asid amino berkualiti tinggi yang baik dan kedua-dua kandungan MUFA dan PUFA. Kajian ini menunjukkan peluang untuk menghasilkan produk nilai tambah dari ladang belut dan memproses produk sampingan seperti penambah makanan, suplemen kesihatan dan sebagai bahan untuk ubat topikal. Kajian masa depan perlu dilakukan terutamanya mengenai kesan kaedah pengeringan atau penggunaan bahan tambahan lain dalam makanan semasa pengeringan semburan terhadap kualiti serbuk.



TABLE OF CONTENTS

APPROVAL.....	i
DECLARATION	ii
ACKNOWLEDGEMENT	iv
ABSTRACT.....	v
ABSTRAK.....	vii
LIST OF TABLES	xiii
LIST OF FIGURES	xiv
LIST OF SYMBOL AND ABBREVIATIONS.....	xvi
CHAPTER 1: INTRODUCTION	1
1.1 Background of study	1
1.2 Problem Statement	4
1.3 Objectives.....	4
1.4 Scope of Study.....	5
CHAPTER 2: LITERATURE REVIEW	6
2.1 Eel (<i>Monopterus Albus</i>)	6
2.1.1 Nutritional value of Asian Swamp Eel (<i>Monopterus Eel</i>)	7
2.1.1.1 Proximate Composition of <i>Monopterus Albus</i>	7
2.1.1.2 Amino Acid Profiling of <i>Monopterus Albus</i>	8
2.1.1.3 Fatty Acid Profiling of <i>Monopterus Albus</i>	9

2.2	Fish Protein Powder (FPP)	11
2.2.1	Spray-Drying	13
2.2.1.1	The stickiness issues during spray-drying	14
2.2.1.2	The utilization of additives as drying aid	16
2.2.1.3	Concentration of additives	20
2.2.1.4	The optimal inlet temperature for spray-drying with addition of maltodextrin	21
2.2.2	Freeze-Drying	22
2.2.3	Oven Drying	23
2.3	Analysis of Fish Protein Powder	24
2.3.1	Physicochemical Properties of FPP	26
2.3.2	Functional properties	28
CHAPTER 3: METHODOLOGY		31
Introduction		31
3.1	Samples /material	31
3.2	Sample Preparation	32
3.2.1	Pre-treatment and Processing of Eel	32
3.2.2	Preparation of Soluble Protein Powder	33
3.3	Spray Drying	33
3.4	Nutrient Analysis	36

3.3.1	Proximate Composition.....	36
3.3.2	Vitamin C.....	36
3.3.3	Amino Acid.....	37
3.3.4	Fatty Acid.....	37
3.4	Analysis of Physiochemical Properties	37
3.4.1	Color.....	37
3.4.2	Tapped Density	38
3.4.3	pH.....	38
3.5	Analysis of Functional Properties	38
3.5.1	Water Binding Capacity.....	38
3.5.2	Protein Solubility	39
3.5.3	Foaming capacity	39
CHAPTER 4: RESULT AND DISCUSSION		41
Introduction		41
4.1	Effects of maltodextrin concentration on process yield and powder condition	41
4.2	The Analysis of Soluble Protein Powder of Eel (<i>Monopterus Albus</i>).....	44
4.2.1	Nutritional values	44
4.2.2	Physicochemical Properties	54
4.2.3	Functional Properties	58
CHAPTER 5: CONCLUSION AND RECOMMENDATIONS		65

5.1	Conclusion.....	65
5.2	Future Work Recommendation.....	66
5.3	Limitations of the Study.....	67
REFERENCES		68
APPENDICES		83



LIST OF TABLES

Table 2.1: Amino Acids Contents in Monopterus albus Extracts.....	9
Table 2.2: The various classifications of protein powders.....	26
Table 2.3: Protein powders made from various fish muscles that has been shown to exhibit functional properties.....	28
Table 4.1: The process yield, outlet temperature, feed flow rate and powder conditions of FPP with different maltodextrin concentration under constant temperature (160°C)	42
Table 4.2: The Proximate Composition of FPP powder with different maltodextrin concentration under constant temperature (160°C)	44
Table 4.3: The vitamin C FPP powder with different maltodextrin concentration under constant temperature (160°C)	47
Table 4.4: The composition of Amino Acid in Monopterus Albus	49
Table 4.5: The Amino Acid Composition in Monopterus Albus Extract	51
Table 4.6: The color of soluble protein powder of eel.....	54
Table 4.7: The tap density and pH of FPP powder with different maltodextrin concentration under constant temperature (160°C)	57
Table 4.8: The water binding capacity, protein solubility and foaming capacity of FPP powder with different maltodextrin concentration under constant temperature (160°C) ...	60

LIST OF FIGURES

Figure 1.1 Fish Protein Powder.....	2
Figure 2.1 Eel (<i>Monopterus Albus</i>)	6
Figure 2.2: Spray-dryer and its process flow diagram	13
Figure 2.3: The stickiness of feed to the drying chamber	15
Figure 2.4: The stickiness of feed to the cyclone powder collector.....	15
Figure 2.5: Maltodextrin	17
Figure 2.6: Gum Arabic	20
Figure 2.7: Freeze-dryer and its process flow diagram.....	23
Figure 2.8: Oven-dryer.....	24
Figure 3.1: The eel packed in frozen box from supplier	32
Figure 3.2: The process flow chart of soluble protein powder of eel (<i>Monopterus Albus</i>)	34
Figure 3.3: The process flow diagram of soluble protein powder of eel (<i>Monopterus Albus</i>)	35
Figure 4.1: The graph of yield of powder of FPP at different maltodextrin concentration with constant inlet temperature (160°C)	42
Figure 4.2: The graph of vitamin C of soluble protein powder of eel	47
Figure 4.3: The graph of color of soluble protein powder of eel	54

Figure 4.4: The graph of tap density of soluble protein powder of eel.....	54
Figure 4.5: The graph of pH of soluble protein powder of eel	55
Figure 4.6: The graph of water binding capacity of soluble protein powder of eel.....	60
Figure 4.7: The graph of protein solubility of soluble protein powder of eel.....	60
Figure 4.8: The graph of foaming capacity of soluble protein powder of eel.....	60



LIST OF SYMBOL AND ABBREVIATIONS

a*	Redness/Greenness
Ag	Silver
AgCl	Silver Chloride
AOAC	Association of Official Agricultural Chemists
b*	Yellowness/Blueness
CIE	International Commission on Illumination
DB	Dry-basis
EPP	Eel Protein Powder
FAO	Food and Agriculture Organisation
FDA	Food and Drug Administration
FC	Foaming capacity
FPC	Fish Protein Concentrate
FPH	Fish Protein Hydrosylate
FPP	Fish Protein Powder
FPI	Fish Protein Isolate
L*	lightness
MD	Maltodextrin

mg	Milligram
mL	Milliliter
nd	Not detected
pH	Power of Hydrogen
rpm	Rotation per minutes
SFA	Saturated Fatty Acid
t	time
WBC	Water binding capacity
WFP	Whole Fillet Powder
WHO	World Health Organization
w/w	weight/weight
%	Percentage
>	More than
<	Less than

CHAPTER 1

INTRODUCTION

1.1 Background of study

As a result of the coronavirus illness 2019 (COVID-19), the usage and sales of nutritional supplements have surged globally (Hamulka et al., 2020). People are started to consume additional supplement such as vitamins and protein powder to take boost their immune system as well as to provide overall wellness to the body. The market needs for fish protein components, such as dried fish protein, to make functional foods and ready-to-eat foods is progressively increasing (Thorkelsson et al. 2009). Fish protein powder (FFP) is an example of supplement that act as meal replacement that contained all nutrients that body required (Shaviklo et al., 2010)

Fishes have an important part of human civilization in terms of nutritional, economic, cultural, and recreational advantages since they are believed to be the greatest providers of protein (Lynch et al., 2016). Since fish contains all of the necessary amino acids and is easily digested, it is a great source of high-quality protein (Wijayanti & Setiyorini, 2018). Fish with white flesh and little fat content are regarded ideal for the production of fish protein components (Hultin et al. 2005; Park and Lin 2005). According to Ashitey and Flake (2010), fish is a less costly and more popular animal protein source.



Figure 1.1 Fish Protein Powder

Fish protein powder (FPP) is the best substitute meal for people that face a struggle to eat a fresh fish due to the strong smell, flavour and texture of fresh fish itself. Generally, fish protein powder (FPP) is a dried and stabilized fish product that is suited for human utilization and contains higher protein than the actual fish flesh (Shaviklo et al. 2011). The protein content of fish protein powder (FPP) differs based on the raw materials used, the amounts of additives employed, and the moisture content of the product, but it always includes at least 65 percent proteins (Sen,2005). Numerous research has shown that FPP has a high potential for lowering cancer, ageing, diabetes, and cardiovascular disease risks.

Monopterus Albus, known as Asian swamp eel or a common air-breathing fish. It has a snake-like body and a rounded, blunt nose. Its slick skin is usually darker green or brown on top and lighter on the bottom (Bricking, 2002). The fish is known to have benefits to cut cholesterol, blood pressure, and arthritis risk as well as improve stamina in our body. Halim & Sarbon (2017) studied that eel possess 83.87% of moisture, 16.88% of protein, as well as 3.41% of fat and 0.89% of ash. The eel, which is a healthy and

appetising species, is also regarded as a valuable treatment in eastern medicine (Khanh and Ngan, 2010).

According to customers preference, the nutrition of eels was extracted into liquid and powder form to develop a pharmaceutical product for human health. For example, the head of eel was turned into powder form to treat the people that suffered from depression (Anastasya et al., 2020). Other than that, eels also were consumed in the liquid form especially for elderly as nutritional extracts to increase the metabolism in the body. Liquid form of eel extracts frequently poses problems of limited shelf life, physicochemical instability and restricted maneuverability due to presence of heavy weighted water (Hui et al., 2010). Thus, preparation of the eel in powder form might be of interest to food industries. However, this can only happen when there is an increase in fish supply (Dash et al., 2014).

The spray drying is the commercialized process used to produce high quality FPP in the industrial scale. Fast evaporation of fluid from a sprayed solution in a drying chamber is a common industrial process for drying items. However, there have been numerous obstacles in the way of reaching high efficiency during spray-drying (Sosnik & Seremeta, 2015). The commercialization value of the spray drying process has often valued several parameters, including process yield, end product characteristic, and production cost. Low glass transition temperatures of feed materials, which are often present in fruit juice and highly acidic feed materials, are a problem that frequently reduces process output (Shishir and Chen, 2017).

This study is part collaborative project, with the company in Terengganu that aims at developing fish protein powder from (*Monopterus Albus*) and using spray dryer.

1.2 Problem Statement

The origin and processing methods of fish protein raw materials have an impact on its quality and properties (Shaviklo et al. 2010; Arason et al. 2009). As a result, readily available powder varies greatly in its quality and compositions. In order to meet rising worldwide demand for fish protein components for functional meals and ready-to-eat goods, the industry must discover new ways of producing fish protein ingredients from various source materials. This study provides a solution based on industry demand - to produce fish protein powder from locally breed eel and characterize the powder. The results collected from this study can provide additional data to contribute knowledge to determine its market potential.

1.3 Objectives

A small- and medium-scale processing facility in Terengganu raised eels for the research, which aimed to make eel protein powder from it and evaluate the nutritional, physicochemical and functional properties of the powder. The objectives of this researched were:

- 1) To produce fish protein powder from *Monopterus Albus* by addition of drying aid at different concentration which are 25% and 100% maltodextrin concentration.
- 2) To investigate and compare the effects of maltodextrin concentration at constant inlet temperature on the nutritional, physicochemical and functional properties of the powder.

- 3) To implement the spray-drying method to dry the soluble protein juice of eel into eel protein powder.

1.4 Scope of Study

There are two research scopes were carried out to achieve the objectives:

1. Extraction the soluble protein from *Monopterus Albus* using method adapted from company in Terengganu and Shaviklo et al. (2012). Then, turn it into powder using spray dryer process at different concentration of maltodextrin
2. Determination of nutritional, physiochemical & functional properties of fish protein powder. The characteristic of powder was determined to design processing, storage, and conveying systems of particulate materials. The analysis was conducted on color, pH, tap density water binding capacity and protein solubility and foaming capacity of fish protein powder.

CHAPTER 2

LITERATURE REVIEW

2.1 *Monopterus Albus* (Swamp Eel)

The rice eel (*Monopterus Albus*), commonly known Asian swamp eel or 'belut sawah' in Malaysia, is a commercially significant air-breathing fish Synbranchidae family (Nico et al. 2019). It is found throughout East and Southeast Asia, commonly consumed as a healthy meal. The body of swamp eels resembles that of an eel. Males are approximately 60 cm long; females are around 20 cm long and intersex individuals are approximately 30–40 cm long. Their bodies are golden and brown in appearance, with black specks strewn throughout them (Cheng et al., 2021). The studies found the eels quit the feeding at 14-16°C and died at 8-9°C (Shafland et al., 2010).

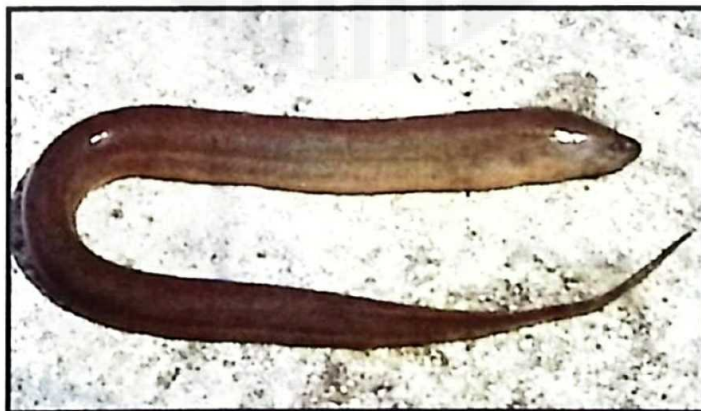


Figure 2.1: *Monopterus Albus* (Swamp Eel)

Amino acids and fatty acids are dominate in *Monopterus Albus*. *Monopterus Albus* is often applied in medicine as well as being eaten. Fat 1.77 g / g fillet and DHA 9.4 g / 100g oil is extracted from *Monopterus Albus* (Di & Kiew, 2010). Other fish species that having the similar DHA content is cod and salmon. The growth of *Candida albicans*, *Candida krusei*, *Cryptococcus neoformans*, and *Fusarium* species can be inhibited by using the extract of mucus from *Monopterus Albus* (Nik Mohd Ikram et al., 2013). *Monopterus Albus* is also known to contain proteins and various amino acid content. The production of *Monopterus Albus* has grown, resulting in the availability of high-quality eels. Feed and aquaculture systems are important features of Asian swamp eel aquaculture (Fujiani et al., 2015).

2.1.1 Nutritional value of *Monopterus Albus* (Swamp Eel)

2.1.1.1 Proximate Composition

Muslimatun Arizal et al. (2018) studied the proximate composition of *Monopterus Albus*, and the result was recorded. The result showed that the *Monopterus Albus* had a high protein and low lipid content. The protein content ranges from 50.07 % to 74.31 %, while the lipid content is between 2.26 % to 2.66 %.

Vivi Endar Herawati et al. (2018) have investigated the growth performance and nutritional quality of Asian Swamp Eels (*Monopterus Albus*) in a Freshwater Aquaculture System with various diets in Central Java, Indonesia. It is reported that the Asian Swamp Eel (*Monopterus Albus*) is a high-protein meal which is approximately 81.25%. *Monopterus Albus* may be classified as an average lipid fish since its lipid content ranges from 2.26 percent to 2.66 percent in samples. In contrast to Common silver barb (*Puntius gonionotus*), Nile tilapia (*Oreochromis niloticus*), and other freshwater fish studied in

Thailand; the eel has the lowest lipid content (Puwastien et al., 1999). *Monopterus Albus* is good for low-fat dieters, cardiovascular patients, and hyperlipidemia patients since it has an adequate lipid content (Bae et al., 2011).

2.1.1.2 Amino Acid Profiling

Febriyenti et al. (2019) had analyzed the eel's amino acids and fatty acids in two parts: the body and waste (head and tail). Glycine (5.26 mg/g), alanine (4.39 mg/g), phenylalanine (2.16 mg/g), lysine (1.88 mg/g), proline (1.84 mg/g) and arginine (1.73 mg/g) are the important amino acid in the extract of rice eel. Based on the result, glutamic acid (Glu) had the greatest amino acid level in both body and waste samples, with 2.44g/100g in the body sample and 1.71g/100g in the waste sample. Aspartic acid, glycine, arginine, threonine, and leucine are the other major amino acids. Other amino acids are less than 1% in 100 g sample. These acids are beneficial for skin health, such as pH balance, skin hydration, skin firmness (anti-aging), skin repair, wound healing, and antioxidants.

Polypeptide binding binds 20 monomer amino acids to form a protein. Collagen has a significant amount of glycine. Glutamate is being used by inflammatory cells within the wound for proliferation and as a source of energy. Protein and nucleic acid synthesis are carried out by fibroblasts using glutamine. Arginine is required for wound healing and immunological function. In comparison to other eel species, it had a comparable overall amino acid composition pattern, although there were minor differences in the compositions of individual amino acids. In reality, *Monopterus Albus* has a slightly greater quantity of amino acids; 16.94g and 16.22g in 100g extract for body and waste, respectively.

Table 2.1: Amino Acids Contents in *Monopterus Albus* Extracts

No	Amino Acid	Contents (mg/ 1 g content extract)			
		B1	B2	B3	Mean
1	Aspartic acid	0.46	0.52	0.58	0.52
2	Serin	0.88	0.92	0.96	0.92
3	Glutamic acid	1.23	1.23	1.24	1.23
4	Glycine	4.50	5.71	5.57	5.26
5	Histidine	1.10	1.17	0.00	0.76
6	Arginine	1.74	1.74	1.70	1.73
7	Threonine	1.27	0.00	0.00	0.76
8	Alanine	4.32	4.43	4.42	4.39
9	Proline	2.00	1.82	1.71	1.84
10	Tyrosine	0.24	0.29	0.22	0.25
11	Valine	1.24	1.37	1.47	1.36
12	Lysine	1.86	1.93	1.86	1.88
13	Isoleucine	0.39	0.00	0.00	0.13
14	Leucine	1.13	1.31	1.29	1.24
15	Phenylalanine	1.36	2.92	2.21	2.16

2.1.1.3 Fatty Acid Profiling

According to Febriyenti et al. (2019), fatty acids are essential for lipids (fat-soluble components of living cells). The total fatty acid composition of the body of eel was determined to be 0.11g/100g sample, with saturated fat being the most abundant, followed by monounsaturated fat and polyunsaturated fat. Meanwhile, the total fatty acid composition of the eel's waste was discovered to be higher than that of the body, at 0.17g/100g, with saturated fat leading, followed by monounsaturated fat and polyunsaturated fat. The dominant fatty acids found in an eel's body are palmitic,

arachidic, pentadecanoic and lauric acid for saturated fat with a percentage of more than 8%. For monounsaturated fat with a percentage of more than 8%, the acid founds are oleic and nervonic. Then, in the waste section of the eel, myristic and stearic acids were found to be prominent, whereas α -Linoleic acid had a low percentage of fatty acid. Di & Kiew (2010) had investigated the nutrient composition of eel (*Monopterus Albus*). Despite the low-fat content (1.8%), According to the result, *Monopterus Albus* has a high percentage of docosahexaenoic acid (DHA). The value obtained in this study (9.4g/100goil) was comparable to that of sockeye salmon (Pacificher) (0.71g/100gtissue). These species are well-known for being excellent suppliers of fatty acids.

In contrast to saturated fatty acids, linoleic acid in *Monopterus Albus* oils indicated that the oil was a light oil that could readily permeate human skin. Linoleic acid has found use in various industries, especially in the cosmetics industry, due to its multiple beneficial effects (Zielinska et al., 2004). Linoleic acids have also been shown to aid in the healing process and speed the rebuilding of the skin barrier. All of these fatty acids have been employed as components in skincare products because of their health advantages, which include emollient, antioxidant, cleansing, emulsifying, anti-inflammatory, skin healing, and protection (Febriyenti et al., 2019).

2.2 Fish Protein Powder (FPP)

Fish protein powder (FPP) is a product that contains fish-based ingredients that are purposely produced for the consumption of humans. It is a dried and stable food product where the percentage of protein is higher and more concentrated than the protein content inside the original fish flesh (Shaviklo et al., 2010). Fresh, canned, frozen, smoked, or dried fish have traditionally been the processing techniques utilized for human utilization, with all of them being consumed as a full meal rather than as an ingredient in other dishes. An industry has emerged to produce a fish protein powder for human consumption, driven by advances in refining and processing technology and increased study on fish proteins and peptides (Tahergorabi et al., 2012). Although it is a good source of highly digestible amino acids, its usage is usually limited due to the expensive cost of manufacture (Shaviklo et al., 2010).

Brown, M.J. (2017) studies that fish protein powder (FPP) has a lot of advantages to the health of overweight and obese adults. This is because the people who consume protein-rich meals and supplements feel fuller for longer periods. Therefore, humans can consume fish protein powder to maintain a healthy weight or obtain the ideal weight. Besides that, protein is a nutrient that aids in developing muscle, tissue repair, and the production of enzymes and hormones (Leonard. J, 2018).

The protein level of fish powder varies depending on the raw materials used, the number of additives used, and the moisture content, but it must include at least 65 % protein (Shaviklo et al., 2012). Sathivel et al. (2014) had studied the nutritional qualities of herring and arrowtooth fish, and the analysis of samples had outstanding nutritional values and included 63–81.4 percent protein. Moreover, the higher protein content of fish

protein content than the fat content is suitable for daily consumption to help build the muscle and repair the tissue. The potential of protein that can be digested or NDF digestibility from the fish flesh is around 90 to 98 % (Shaviklo et al.,2010). The protein composition of fish protein powder was also influenced by filler utilization during manufacturing. The addition of high protein content of filler causes the resulting fish protein powder to increase protein composition (Fawzya et al., 2020). In this study, fillers aim to reduce stickiness and wall deposition in spray-drying methods.

Due to the essential amino acid pattern, fish proteins have a great nutritive value. Methionine and lysine are the two necessary amino acids in fish proteins, which are higher than most plant-based proteins in these amino acids (Venugopal 2006). The results of fish powder which were reported by Venugopal et al. (1996), Sathivel et al. (2004), Sathivel et al. (2006), and Sathivel & Bechtel (2006), the fish powder produced showed the highest value in glutamic acid. Compared with other fish powder, the powder produced by herring gonad and pollock head reported by Sathivel et al. (2004) and Sathivel & Bechtel (2006) showed the highest value in glycine content. Ahn et al. (2015) reported amino acid content for a different type of eel, and glutamic acid shows the highest value. Other than that, the amino acid content of fish flesh and FPP had no significant differences. Venugopal (2006) studied the amino acid content between raw Cape hake and Cape hake protein powder, and the result was identical.

2.2.1 Spray-Drying

The spray-drying is most favourable process to prolong the shelf life of fish protein powder. Luz et al. (2007) explained that the spray-drying process required intense heat in order to remove the moisture from solid materials. Using a hot gas to quickly dry a liquid or slurry results in the production of a dry powder, or to put it another way, spray drying. The yield of this technique has uniform particle size, making it suitable for a variety of thermally sensitive materials, including foods and medicines (Abadio et al., 2004). As a result, spray-drying process helps to increase the shelf life of food products and reducing the space during distribution and transportation as the food products is turn into small particles of powder (Singh et al., 2013).

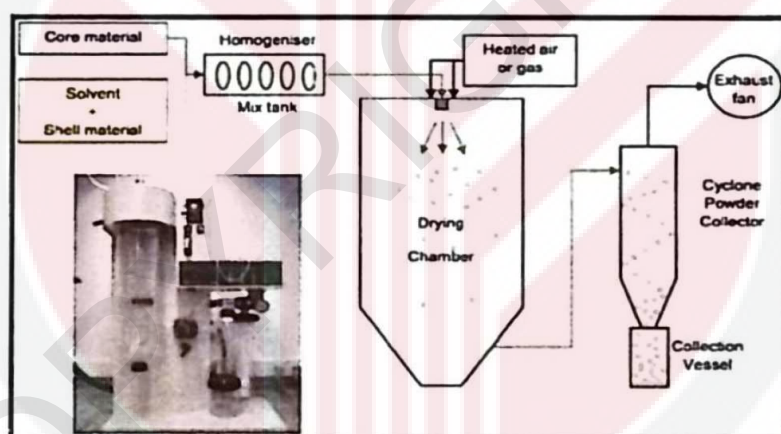


Figure 2.2: Spray-dryer and its process flow diagram

Spray drying is a one-step continuous unit process that uses liquid atomization to create droplets that are transported through a hot gaseous drying medium where they are dried to individual particles. A feed pump, an atomizer, a heater for the air, a dispenser for the air, a drying chamber, and systems for cleaning the exhaust air and recovering or separating the powder make up a spray dryer. Before the dry powder is obtained at the

end process, there are three stages that occurred. This first stage is the atomization, second stage is moisture evaporation and last stage is separation of dry product from the exit air.

The recovery of fish protein powder is one of the biggest issues when making powder via spray drying. The viscosity of fish flesh, the temperature of spray drying, and an increase in recovery rate with lower moisture all have an impact on FPP recovery (Niki and Igarashi 1982). The viscosity of the fish flesh sol has an impact on the fish protein powder particle size as well. High viscosity promotes the growth of large fish protein powder particles and huge droplets of fish meat sol. Large droplets clash with the bottom and wall of drying chamber, which reduces the amount of fish protein powder recovered (Niki et al. 1983). By adding carbonic acid and lowering the pH to the isoelectric point of protein, the viscosity of fish flesh sol may be lowered. Carbonic acid rapidly breaks down into carbon dioxide and water after drying and is not retained in the fish protein powder (Niki and Igarashi 1982). As a result, the pH of the fish protein powder becomes neutral and the amount of denaturing fish protein (actomyosin) is reduced (Niki et al. 1983).

2.2.1.1 The stickiness issues during spray-drying

It is hard to retrieve powder when applying spray drying method for material that is rich in sugar and acid because of the presence of low molecular weight sugars (glucose, fructose) and organic acids (citric, malic, and tartaric acid). Owing to its high hygroscopicity, low glass transition temperature (T_g), and thermoplasticity, these low-molecular-weight factors determine to the stickiness problem (Du et al., 2014). At spray drying temperatures beyond $T_g + 20^\circ\text{C}$, these substances have a potential to generate soft granules with a sticky texture, which makes the powder stickier and eventually causes the creation of a paste-like structure instead of a powder. As a result of their low glass

transition temperature (T_g), these molecules have great diffusion rate, which results in a stickiness problem at temperatures normally seen in spray dryers (Master. K, 2015). To increase the glass transition temperature (T_g), maltodextrin is introduced to fish protein juice, which reduces the stickiness of the powder in the drying chamber and increases the amount of powder produced in the process.



Figure 2.3: The stickiness of feed to the drying chamber.

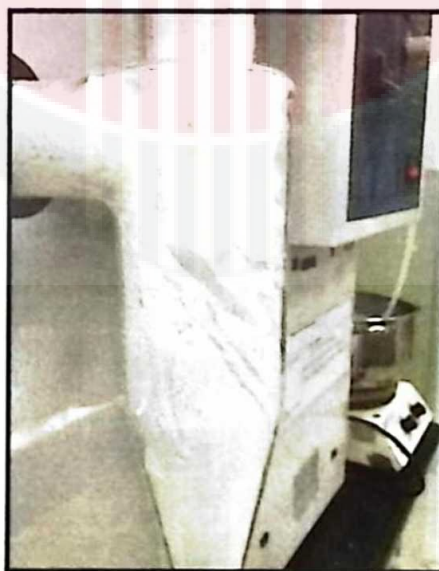


Figure 2.4: The stickiness of feed to the cyclone powder collector.

2.2.1.2 The utilization of additives as drying aid

In order to increase the shelf life of the food, the drying process is required to reduce the moisture from the food (Jayas, 2016). Therefore, the process of drying by using mechanical machine such as spray dryer and oven dryer were required to concentrate the water from the solution by using the mechanism of heating by hot air (Velić et al., 2003). The most popular industrial procedure for solvent removal that involves drying and particles development is spray drying. However, the main problem with the application of spray drying is the stickiness (Ekpong & Onsaard, 2019). Stickiness is a phenomenon that commonly happens when sugar- and acid-rich food ingredients are sprayed dried. A cohesion-adhesion is the characteristic of powder stickiness. Therefore, in order to minimize the stickiness of powder to the wall of spray drying chamber, the additives, were used during the drying process as a drying agent (Muzaffar, 2015).

Major types of commercially available additives for spray drying include carbohydrates (hydrolysed starch, maltodextrin, dextran, cellulose, and derived), gums (Arabic gums, agar, carrageenan), proteins (gluten, casein, albumin, haemoglobin, and peptides), lipids (wax, paraffin, diglycerides, and peptides), and biopolymers. A small number of journals have just recently identified the importance of spray drying applications employing lipid and biopolymers.

Maltodextrins are starch-derived oligosaccharides with dextrose equivalents (DE) of under 20. Maltodextrin has shown effective in reducing wall deposition when used as a drying aid (Langrish et al., 2007). Maltodextrin serves a variety of purposes, such as reducing nutrient losses, improving powdered appearance, reducing sweetness, preventing melting, and averting or delaying granulation. It may also be used as a filler component

(Marcus, 2019). The utilization of maltodextrin was applied in drying process of pineapple (Abadio et al., 2004), and milk powder (Mulyadi et al., 2012). Furthermore, maltodextrin also used in the process of protein concentration of protein meal such as for saithe protein (Shaviklo et al., 2010) and chicken powder (Kurozawa et al., 2009).

According to the study by Shaviklo et al. (2010) on fish protein powder of saithe, the addition of maltodextrin increases the stability of the powder during spray-drying process. Moreover, Peng et al. (2013) also reported that the maltodextrin prevents the oxidation by giving fully protection to the powder in the spray-dryer. This is because maltodextrin acts as a coating on the particles of the feeds. The layer of coating on the particles of feed would increase the endurance of encapsulated ingredients towards high temperatures and pressures during spray drying, therefore, the nutritional value and physical appearance of the resulting powder is preserved. a carrier agent, which protects encapsulated ingredients (Marcus, 2019).



Figure 2.5: Maltodextrin

Moreover, when maltodextrin was added to the solution of the feed during spray-drying, the density of the resulting powder would increase as well as reduce in the wall friction angle. Additionally, maltodextrin change the microparticles of the solution by making the particle smoother, smaller and less agglomerated (Araújo et al., 2020). Thus, the high maltodextrin concentration added produced very small particles of powder. Very small particles have poor flow characteristics and cohesiveness due to attraction forces including Van der Waals, electrostatics, and surface tension. The flow of the powders likewise rises with increasing particle size and, beyond a certain point, becomes free flowing.

Maltodextrins are ideal for spray-drying applications, because the high solubility allows a high level to be incorporated into the dryer feed solution, therefore requiring less water removal. In addition, because of their low hygroscopicity, the products are more easily dried (Klinjapo & Krasaekoopt, 2018). Despite this, maltodextrin still has drawbacks of its own. Lee et al. (2018) explained that large maltodextrin molecules were used as additives in a spray drying process, which resulted in a less effective system and significant residual moisture content in powder products.

The following joint drying aid in the drying technique is Arabic gum. Acacia gum is the most popular type of gum additive for spray drying (Arabic). Acacia gums are particularly successful in emulsifying liquids because they contain complex carbohydrates and protein (D-glucuronic acid, L-rhamnose, D-galactose, and L-arabinose in the ratio of 4:2:2:1) (Swenson et al., 1968). The emulsifying activity is directly related to the concentration of protein in acacia gum (Dickinson, 2003; Román-Guerrero et al., 2009). Like maltodextrin and protein, gum Arabic is an excellent option of the type of additives

to boost the glass transition temperature and increase the surface activity by preventing the stickiness of feed to the spray-dryer wall.

However, acacia gum can produce stable emulsions across a larger pH range, making it a superior ingredient for powdered lipid-based products (Minemoto et al., 2002). When spray drying milk, the use of soluble fibre and acacia gum boosted the probiotic viability (*Lactobacillus Paracasei*), whilst acacia gums had a greater yield and have been shown to be beneficial when compared to other carrier-additives when spray drying high sugar feeds like pomegranate juice. According to Abadio et al. (2004) and Goula and Adamopoulos (2005), powdered products that are spray dried with acacia gum lack a crystalline structure and have a reduced bulk density. Despite the excellent properties of Arabic gum, they usually connected to high costs, a narrow range of applications, and contaminants because of supply and quality unpredictability.

On the other hand, acacia gum excels as a component for powdery fat products because it can create stable emulsions over a more comprehensive pH range (Minemoto et al., 2002). At the same time, acacia gums had a higher yield and been demonstrated to be favorable compared to other carrier-additives when spray drying, the addition of soluble fiber and acacia gum increased the probiotic viability (*Lactobacillus Paracasei*) in milk. Powdered items spray dried with acacia gum did not form a crystal structure due to crystalline, thus leading to a decrease in tap density due to lower weight of particles, (Abadio et al., 2004); (Goula and Adamopoulos, 2005). Arabic gum has many great qualities, but due to supply and quality inconsistencies, they are often associated with high prices, a limited number of uses, and impurities.

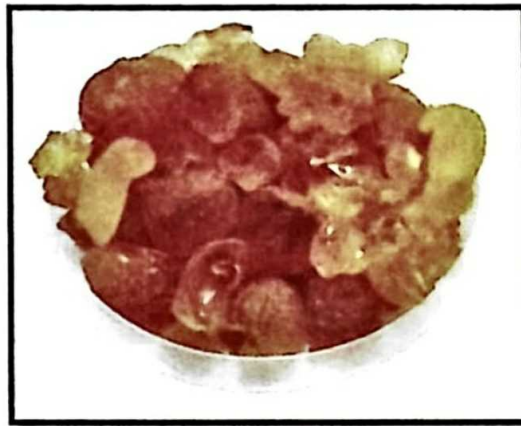


Figure 2.6: Arabic gum

2.2.1.3 Concentration of additives

To increase the physiochemical properties of the fish protein powder, the concentration of additives needs to be control during the spray-drying process. The yield percentage, transition temperature, hydroscopicity, and other physicochemical parameters of the producing powder would change by the high concentration of additives. Shaviklo et al. (2010) had reported the analysis on the nutrition, physiochemical and functional properties of saithe (*Pollachius virens*) with the addition of additives (maltodextrin) and fish juice in the ratio of 1: 1 or 100% maltodextrin concentration. In order to compare the analysis, the saithe juice was then dried through freeze and spray-drying. From the analysis, it is feasible to develop value-added fish protein powder from saithe mince using spray- and freeze-drying processes, but freeze-dried fish protein powder containing additives had superior functional properties and stability than spray-dried sample.

Then, Kanpairo et al. (2012) analyzed the composition, physical properties, and morphology of tuna flavor powder with the addition of maltodextrin at different concentrations, which were 20, 25, and 30%, by using the spray-drying technique. Because the qualities and texture of spray-dried tuna flavor powder produced with the

addition of 25% additives (maltodextrin) concentration are comparable to the ready-mix FPP on the market, the author stated that the attention was most favorable to apply due to constitution, physical properties, and morphology of powder.

Because of the properties of maltodextrin that increase the water solubility, additives are added at more significant concentrations, resulting in powder with reduced moisture content (Khalilian Movahhed and Mohebbi, 2016). However, the amount of maltodextrin added has little impact on the capacity of food to reabsorb water (Grabowski et al., 2006). Similar to this, the protein additive concentration is inconsistently affected the physicochemical properties of the spray-dried powder. A specific quantity of protein supplements increases yield output; however, increasing the engagement produces minor effects (Adhikari et al., 2009)

2.2.1.4 The optimal inlet temperature for spray-drying with addition of maltodextrin

In analyzing the impact of maltodextrin and spray drying heat on fish protein powder, the air inlet temperature was discovered to be the most crucial factor. Due to its capacity to alter the initial drying rate, heat transfer rate to particles, and effectiveness of the heat and mass transfer process, air input temperature impacts powder attributes such as moisture content, hygroscopicity, and shape.

In the first part of the experiment, the spray-drying of eel juice with the addition of maltodextrin was repeated at 160, 170, 180, and 190°C. The selection of inlet temperature was based on observations made during preliminary work on spray-dried eel soluble protein powder, in which the powder that was spray-dried at a temperature of 180°C and 190°C appeared sticky and wet due to the incorporation of steam water inside

the collection vessel while at a temperature above 170°C was yellowish due to burning. Moreover, at the inlet temperature of 160°C, no steam water flowed into the cyclone powder collector and collection vessel, and thus the powder appeared fine and dry. The powder yield at 160°C is also higher than that of powder at 170, 180 and 190°C. Therefore, the inlet temperature of 160°C was chosen as the parameter during spray-drying of soluble protein of eel with the addition of maltodextrin.

2.2.2 Freeze-Drying

Freeze drying is a standard method used to create protein powders. By using the freeze-drying process, the product is frozen and subsequently dried in a vacuum chamber under high pressure and temperatures. Secondary drying occurs after primary drying, which eliminates non-frozen bound water from a freeze-dried sample (Cordova-Murueta et al., 2007). Frozen proteins have their physical environment significantly altered, creating stressors that harm protein structure and stability. Proteins, therefore, must withstand each of these various stresses (Sathivel and Bechtel 2006). Lyoprotectants, such as saccharides, amino acids, and sugar alcohols, are used during the freeze-drying process to protect the proteins from degradation (Huda et al., 2012).

Drying by freezing does not affect myofibrillar proteins (Roy & Nath Gupta, 2004). This is because the structure of the freeze-dried protein in fish is very flexible to be utilized for a wider variety of potential uses. Phases critical to synthesizing freeze-dried fish protein include mixing fish and additives, maintaining plate temperature in a freeze dryer, and packaging and safely storing fish protein (A. R. Shaviklo, 2015). To prevent protein denaturation, cryoprotectants should be added to leached mince on its whole. Plate temperatures of 55°C are ideal for making FPP (Shaviklo et al. 2010a, 2012). With proper

packaging, FPP may be kept for lengthy periods, but if stored at temperatures over 30 °C, it soon loses its ability to perform its intended functions. Frozen fish protein may last for up to nine months in low-temperature storage (18 °C) (Carvajal et al. 2005). To maintain a vacuum condition and maintain a low temperature, freeze drying is the most expensive drying technology currently used in our culture (Ratti, 2008).

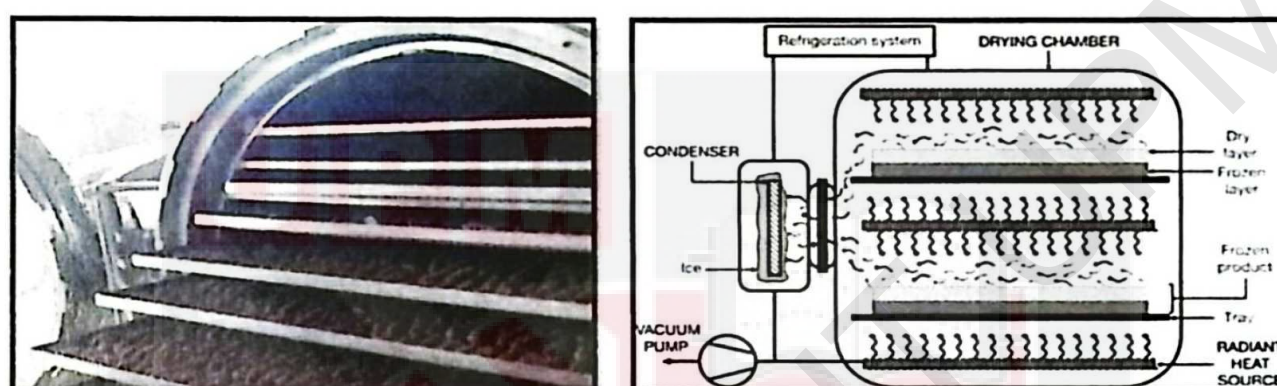


Figure 2.7: Freeze-dryer and its process flow diagram

2.2.3 Oven Drying

The oven drying technology has been shown to generate dried fish protein at a low cost (Chavan et al., 2008). To test if fish croaker mince is utilized in culinary products, the prototypes are dry for 12 hours at 43–45°C. The fish protein powder of lizardfish functional properties was evaluated at oven drying temperatures of 50, 60, and 70 degrees Celsius (Huda et al., 2000). To achieve a moisture content of less than 10%, it was recommended FPP dry for 12 hours at 60 °C. On the other hand, oven-dried fish proteins lacked functional properties compared to spray-dried or freeze-dried fish proteins (Cordova-Murueta et al., 2007; Chavan et al., 2008; Huda et al., 2012).

VLT (shallow temperature) processing was considered in the development of FPP. High protein content, original flavor, and moisture level are all preserved by the VLT process, which uses the most up-to-date technology. Dried fish mince is then reheated for about an hour temperature of 50°F. After grinding, the material is vacuum-sealed for storage (Herrmann et al. 2006).



Figure 2.8: Oven-dryer

2.3 Analysis of Fish Protein Powder

Because the digestible chemical composition of fish muscle differs greatly amongst most fish of the similar species, it is unsuitable for use as a raw food source, posing issues for the food processing industry (Kristinsson and Rasco, 2000). Based on the information from FAO Fisheries and Aquaculture Department, the three groups of proteins obtain from fish muscle.

(i) Structural proteins

This category contains the majority of the proteins found in fish. The protein extract from this part is approximately 70-80% from the total protein content of fish. Most of these

proteins can be dissolved in 0.5M salt solutions with high ionic strength. Actin, myosin, tropomyosin, and actomyosin are types of structural proteins. In fish, these muscles are crucial for muscular movement

(ii) Sarcoplasmic proteins

About 25-30% of the protein inside fish is accumulate by sarcoplasmic proteins. These proteins are generally dissolved in neutral salt solutions with a moderate ionic strength of 0.15M. Myoalbumin, globulin, and enzymes are examples of sarcoplasmic proteins; however, majority of them are enzymes engaged in cell metabolism.

(iii) Connective tissue proteins

Approximately 3% of the protein in Teleostei and 10% in Elasmobranchii is derived from this kind of protein. A protein found in connective tissue is collagen. Compared to collagen from warm-blooded vertebrates, fish collagen is significantly more vulnerable to heat degradation or decomposition, but it also contains fewer and more flexible crosslinks.

The biological benefits of fish muscle protein powders are well recognized. Studies on the development of powdered forms of fish have sparked attention in recent years since fish muscles are typically abundant in amino acids and a readily digested protein. Furthermore, since powdered proteins are lower in weight and have less water activity, they are more portable and stable (Hui et al.,2010). Various powders are now available, typically classed based on their fat and protein composition.

Table 2.2: The various classifications of protein powders.

Type	Classification	Source
Fish Protein Isolate (FPI)	-More pure than FPC -Protein content of >90% -Fat content of <1%	Shaviklo et al.,2006
Fish Protein Concentrate (FPC)	A virtually odourless and tasteless powder having a maximum total fat content of 0.75%	Food and Agriculture Organization of the United Nations (FAO), 1969
Fish Protein Hydrolysate (FPH)	-Peptides of different length broken down chemically or enzymatically from proteins	Kristinsson and Rasco, 2000
Fish Protein Powder (FPP)	-Food grade powder product intended for human consumption	U.S. Food and Drug Administration (FDA)
Fish Meal	-Used in the making of animal feeds -The food is not intended for human consumption	FAO, 1969

2.3.1 Physicochemical Properties of FPP

The colour of the fish protein component is an essential quality factor. The colour and texture of powder produced by using spray-drying is important to attract the customers to buy the products. Depending on the kind of feedstock and additive concentration utilized, the use of additives may either retain or change the physical appearance of the powders, especially the colour (Grabowski et al., 2006). The colour of FPP is influenced by the type of fish used but the usually ranges from light grey to creamy or pinkish. The processing method applied also can affect the colour of resulting fish protein powder. Shaviklo et al. (2010) studied the comparison colour of FPP produced using the freeze

and spray drying method. From the observation, the pinkish colour is derived from leached saithe during freeze-drying process while the leached saithe that were spray-dried exhibited a white colour, indicating that the drying process impacted the FPP quality. The colour of FPP powder with maltodextrin concentration more than 15% would change according the colour of the additives (Abadio et al., 2014). Since most research concentrated on yield output, moisture content, and other factors, there are not many studies on the impact of additives on the powder colour index overall.

One of the essential aspects during development of FPP is the pH of the fish flesh (Niki and Igarashi, 1982). Fish flesh with a neutral pH may be used to generate functional FPP, while fish flesh with an acidic or alkaline pH cannot be used to make functional FPP (Geirsdottir, 2005; Shaviklo et al., 2012). As a result, drying process causes the FPP to become very sensitive. While freeze drying saithe and Cape hake, and drying herring using a heat pump fluidized bed dryer, the samples were found to have poor functional properties (Geirsdottir, 2005). According to the findings, the dried samples exhibited a strong rotten odor and a dark yellowish or grey color. FPP powder failed to gel or hold water very effectively, as was discovered (Geirsdottir, 2005; Shaviklo et al., 2012). The drying of fish protein hydrolysate yielded similar findings (Bragadottir et al., 2007).

2.3.2 Functional properties

Proteins are known for offering non-nutritive functionalities such as solubility, gelation, foaming, and emulsification, in addition to their nutritional capabilities. These functional qualities are significant during the formulation of food products since they are some of the most important aspects of proteins. Fish muscle protein, like other regularly used proteins, may have functional properties. Table below is the variation of fish protein powders that have been proven to have functional qualities in previous study.

Table 2.3: Protein powders made from various fish muscles that has been shown to exhibit functional properties

Fish Source	Drying Method	Functional properties	Source
Arrowtooth Flounder (<i>Atheresthes stomias</i>)	Freeze-dried	Emulsifying and fat adsorption capacity	Sathivel et al., 2004
Herring (<i>Clupea harengus</i>)	Freeze-dried	Emulsifying stability and foaming capacity	Liceaga-Gesualdo and Li-Chan, 1999
Red Salmon (<i>Oncorhynchus nerka</i>)	Freeze-dried	Solubility, fat adsorption, water adsorption and emulsification stability	Kristinsson and Rasco, 2000
Alaska Pollock (<i>Theragra chalcogramma</i>)	Freeze-dried	Solubility, fat adsorption and emulsion stability	Sathivel and Betchel, 2006
Carp (<i>Catla catla</i>)	Oven dried	Foaming capacity and stability	Elavarasan et al., 2014
Saithe (<i>Pollachius virens</i>)	Spray-dried	Water binding capacity, Solubility and, Foaming properties	Shaviklo et., 2010

The functional properties of fish protein powder are affected by the type of drying process and physicochemical changes occurring in proteins during drying seem to affect the quality of the dehydrated product. Therefore, the same raw material may end up as a completely different product, depending on the type of drying method and processing conditions (Shaviklo et al. 2010a, 2012).

To create the desired food texture for consumers, water binding capacity (WBC) is significant, notably in meats foods (Zayas, 1997b). The displeasing texture of the food may cause if the WBC of proteins ingredients is too high. Other than that, the food ingredients with low WBC had problems with the storage condition incredibly humid. In food formulation, choosing proteins with the right WBC is essential. The WHC of proteins is nonetheless influenced by various intrinsic, extrinsic, and environmental variables, including pH, ionic strength, and temperature (Haque et al., 2016). Due to excessive packaging purging, low WBC in powdered items reduces their aesthetic attraction to customers. For processors, the increasing content of WBC in meat results in enhanced protein functioning, increased marinade pick-up and retention, and a rise in efficiency of the process (Bowker, 2017)

Associated with other characteristics like emulsification and foaming, protein solubility is a crucial functional characteristic. The pH of the solution and ionic strength are the ones that affect solubility. Different phases of protein unfolding will arise from other pH solutions, affecting solubility. Differences in the concentration of charged ions in solutions with different ionic strengths will interact with amino acid groups with opposing charges. Proteins would precipitate due to reduced water contacts caused by increased charged ion interactions (Lopez-Enriquez et al., 2015).

Examples of features that help the food industries to determine the quality and sensory of the foods are foaming and bubbles. A few food items, including drinks and powdered meals like champagne, wine, beer, milk, and coffee powder, are a natural component of the process. Foaming may help a product find a small market by making it stand out and seem more desirable, as several industry experts have indicated. Wherever feasible, foaming could be a striking improvement to the nature of a food product. A pleasing appearance may be created by lowering the mass per unit area of foams owing to air incorporation, which may benefit the food products. Novel naturalization of proteins will reduce their capacity to create foams, which may aid the creation of foams in drinks (Mauer, 2003).

The foaming capacity of a protein is measured as the amount of interfacial area that can be created by whipping the protein. The diffusion of protein with the interface creates the foaming. The protein is beating, and the bubble appears by the measurement of the interfacial area that the dots can pack. The condition where a flexible cohesive film traps air bubbles and produce a significant amount of foam is vital to determine the characteristic of protein during food processing (Sathivel & Bechtel, 2006). The duration needed to remove 50% of the liquid and foam volume is used to calculate foam capacity. The ability of the protein to foam will often be improved by heating it to partial denaturation. It may adhere to air-water interfaces more rapidly and reduce interfacial tension when the structure expands and exposes hydrophobic areas, increasing the capacity for foaming and trapping more air.

CHAPTER 3

METHODOLOGY

Introduction

In this study, the fish protein powder from eel (*Monopterus Albus*) was developed by using different maltodextrin concentration (25 and 100) %. The end product which is the eel protein powder were analysed to determine the nutritional value and characteristic of powder. The proximate composition (protein, fat, moisture and ash), vitamin C of eel protein powder were analysed. The amino and fatty acid analysis were done only on the eel protein powder at 25% maltodextrin concentration. Lastly, the physicochemical properties (pH, colour measurement and tap density) and functional properties (water binding capacity, protein solubility and foaming capacity) of fish protein powder were analysed to determine the characteristic of powder.

3.1 Samples /material

The freshly packed eel (*Monopterus Albus*) was obtained from the supplier from Terengganu with their length ranging from 38 to 57 cm and width ranging from 4 to 9 cm. The weight of the eel also varies from 0.32 to 0.38 kg. The eel was immediately frozen in the freezer at the temperature of -20°C until further used. For the materials, maltodextrin with weight of 1kg/pack was purchased.

3.2 Sample Preparation

3.2.1 Pre-treatment and Processing of Eel

5 kg of eel (*Monopterus Albus*) was thawed at room temperature of 25°C. Then, the samples were washed by using cold water followed by 2% w/v sodium bicarbonate solution to break down dirt and greasy substances clinging to the surfaces of eel and finally cold water again. After that, the samples were cut manually into small pieces to ease the cooking process. Then, the eels were placed in the cooking pot together with the distilled water at ratio of 1:2 and let to cook at temperature of 100°C for 2 hours (Shaviklo et al., 2010). After the simmering process, the mixture was allowed to cool at room temperature. The homogenization process would take where the mixture was homogenized by using high speed blender for about 2 min. Afterwards, the mixture was centrifuged for 15 min and 2560g by using centrifuge machine (Sathivel et al., 2014). After centrifuge process, the mixture of fish was separated into three layers.



Figure 3.1: The eel packed in frozen box from supplier

3.2.2 Preparation of Soluble Protein Powder

The insoluble protein, bone, and skin were found in the semisolid phase at the bottom; the soluble protein was found in the heavy liquid phase in the middle; and the crude lipids were found in the light liquid phase at the top. Separation and collection of the heavy liquid in the centre were necessary for the following step. The total of 2 kg of soluble protein liquid was collected from 5 kg of eel. Next, the soluble protein solution was separated into two beakers for addition of different maltodextrin concentration.

3.3 Spray Drying

The maltodextrin was stored away from direct sunlight and humid temperature. To prepare the soluble protein with 100% maltodextrin concentration, the same amount of additive (2kg) was added to the solution (2kg) making the ratio between the maltodextrin and soluble protein of eel in 1:1 ratio. For 25% concentration, maltodextrin, 0.5 kg of maltodextrin was added to the solution (2kg) making the ratio between the maltodextrin and soluble protein of eel in ratio of 0.25:1. The soluble protein of eel was heated to 70°C and maltodextrin was added to 25% and 100% concentration. After the right amount of maltodextrin was added to the soluble protein solution, they were then fed into spray-dryer machine. The drying hours for spraying the powder is about 2 hours with the inlet temperature of air at $160 \pm 5^{\circ}\text{C}$. The resulting fish protein powder was collected, weighted and stored at refrigerator. Samples were then tested for physical, chemical, and microbiological qualities to choose the best powder.

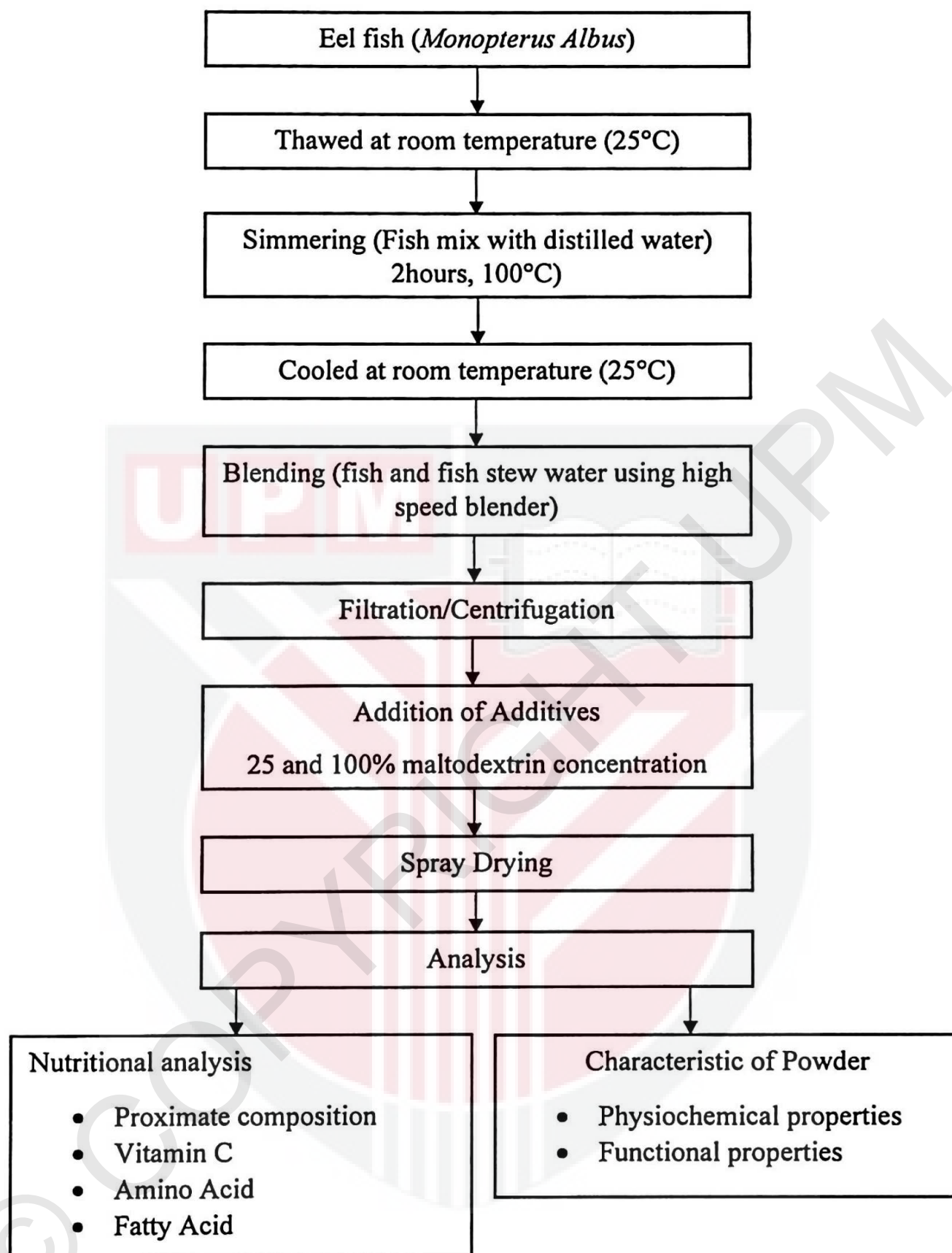


Figure 3.2: The process flow (adapted from Shaviklo et al., 2010)

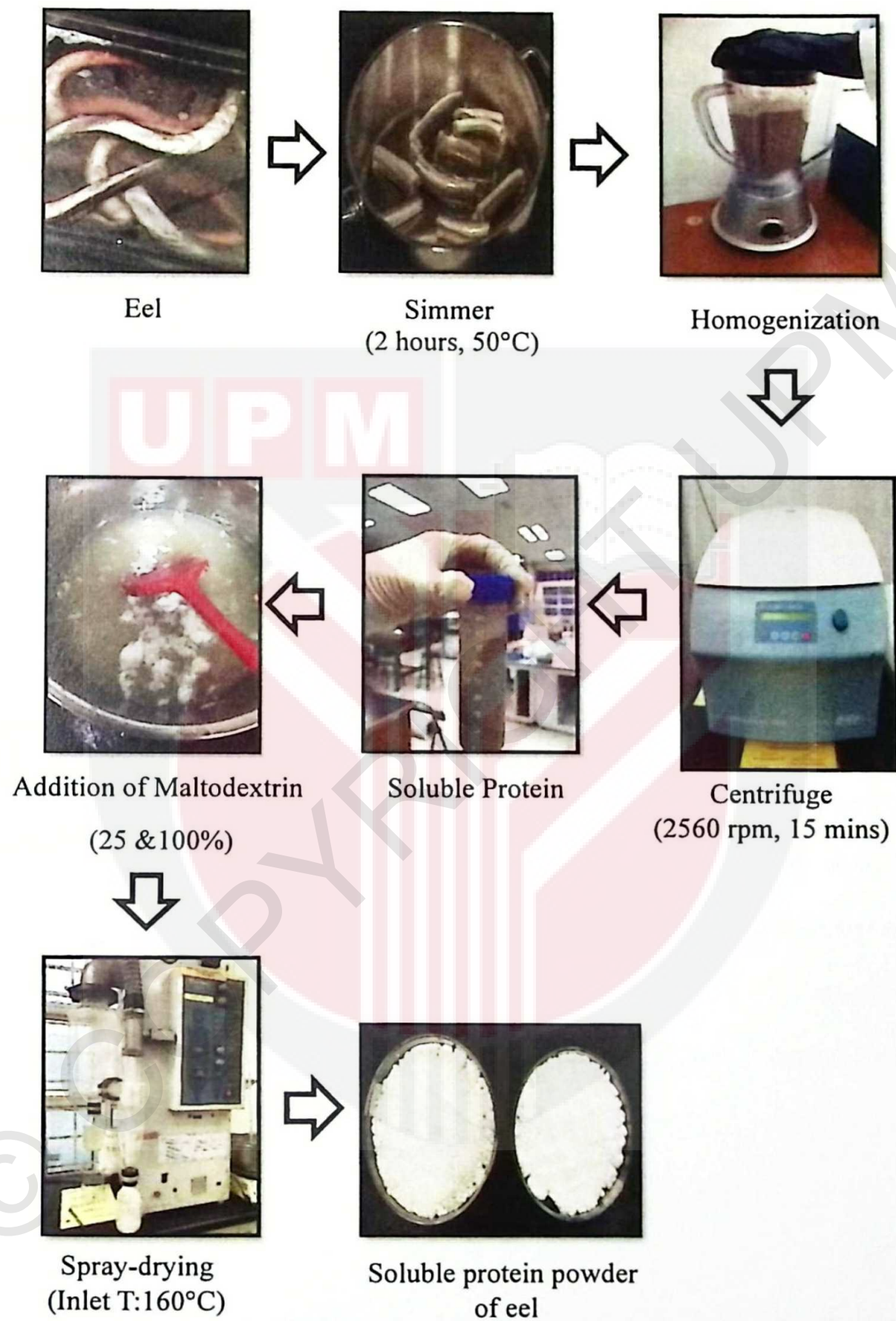


Figure 3.3: The process flow diagram of soluble protein powder of eel (*Monopterus Albus*)

3.4 Nutrient Analysis

3.3.1 Proximate Composition

The AOAC procedures were used to estimate the approximate composition of raw materials and powders in duplicate. The Kjeldahl technique was used to identify the crude protein concentration. The Soxhlet method was used to determine the crude lipid content. Ashing samples overnight at 550°C was used to evaluate ash content. The moisture content of samples was tested by drying them for 4 hours at 105°C until they reached a consistent weight. Difference was used to calculate carbohydrates (Shaviklo et al., 2010b)

3.3.2 Vitamin C

The 2,6-dichlorophenol indophenol titration technique was used to assess vitamin C content. The 2 g of FPP samples were homogenized with 5 mL of metaphosphoric acid-acetic acid solution in 50-mL Erlenmeyer flasks. The samples were filtered, and indophenol dye solution titrated until a light rose-pink hue remained for more than 5 seconds. The initial and final measurements were recorded for each titration and used to calculate the quantity of dye used. The dye quantities used to titrate the samples were compared to a known ascorbic acid standard titration concentration. Vitamin C levels in the samples were computed and represented as follows:

$$\text{mg ascorbic acid/mL} = (X \times B) \times (F/E) \times (V/Y)$$

where:

X = average mL for sample titration;

B = average mL for sample blank titration;

F = titer of dye (= mg ascorbic acid equivalent to 1.0 mL indophenol standard solution);

E = ml assayed (= 2 mL);

V = volume of initial assay solution (= 7 mL);

Y = volume of sample aliquot titrated (= 7 mL).

3.3.3 Amino Acid

Amino acid analysis was conducted on the powdered proteins at 25% maltodextrin concentration. Samples were sent to the Unipeq for analysis. All analyses were conducted according to the Association of Official Analytical Chemists methods (AOAC, 1995; AOAC 982.30 E)

3.3.4 Fatty Acid

Fatty acid analysis was conducted on the powdered proteins recovered at 25% maltodextrin concentration. Samples were sent to the Unipeq for analysis. All analyses were conducted according to the methods described by AOAC (1995). Acidic hydrolysis was used for fatty acid extraction (AOAC 996.06)

3.4 Analysis of Physiochemical Properties

3.4.1 Color

During drying, the colour of the FPP was measured. The CIE (International Commission on Illumination) coordinates, including L*, a*, and b* values, were measured using a portable colorimeter. The colorimeter was calibrated against a white surface standard calibration plate and adjusted to CIE. The figures are the averages of five readings taken from various leaf positions. The coordinate L* coordinated, according to LCM (2016), indicates the brightness value of a colour and varies from black to white at 100. Whenever the chromaticity coordinate a* is negative, it decides green, and when it is positive, it

determines red. When the chromaticity coordinate b^* is negative, it determines blue, and when it is positive, it defines yellow.

3.4.2 Tapped Density

The highest packing density of powder attained underneath the effect of an exterior force is known as tapped density. The tapped density of powders was determined using a tapped density analyzer. After pouring a pre-weighed sample into the graduated glass chamber, the plunger was pushed, and the analyzer was attached. Using the analyzer keyboard, data such as sample name, number of cycles, and applied force were input to begin the analysis. The analyzer compresses the sample chamber during the research. The analyzer pushes the plunger into the chamber while the chamber is being agitated until the necessary consolidation (compression) force (50 N) is reached. The weight of sample was input after the test, and the density in g/cm³ and standard deviation were shown on the LCD screen

3.4.3 pH

The pH of the FPP was determined in duplicate for each sample. Five grams of saithe protein powder was mixed with 20 mL deionized water and stirred for 5 min prior to measurement with an Ag/AgCl combination electrode connected to a pH meter.

3.5 Analysis of Functional Properties

3.5.1 Water Binding Capacity

The Beuchat technique was used to determine WBC in duplicate for each sample. 100 g distilled water was added to 25 g FPP in a centrifuge container. The sample was centrifuged for 30 minutes at 1675 g using a high-speed centrifuge after being let to rest at room temperature for 30 minutes with continuous stirring. Afterward, the supernatant

was weighed and utilised to determine protein solubility, while the remaining powder and liquid collected by the powder were quantified gravimetrically (Shaviklo et al., 2010c).

Results were calculated as:

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

where A = amount of water added to FPP before centrifugation (g), B = amount of water removed from wet protein after centrifugation (g), and C = sample (g).

3.5.2 Protein Solubility

Protein solubility of fish protein powders was determined using the supernatant from the WBC measurement. The crude protein powder as well as the supernatant were tested using the Kjeldahl technique to quantify the quantity of protein ($N \times 6.25$) in each (Shaviklo et al., 2010c). The following equation was used to calculate protein solubility in water (percent) in duplicate for each sample.

$$\text{Protein solubility} = \frac{A}{B} \times 100$$

where A = amount of soluble protein (g) and B = total amount of protein in the FPP sample (g).

3.5.3 Foaming capacity

25g of FPP powder was mixed with 20g of distilled water. The mixture was blended in a high-speed blender for 2 min at the highest speed. For volume measurement, the liquid was carefully transferred to a beaker. FC was computed as the difference between the

volume of the mixture after blending and the initial volume (Shaviklo et al., 2010). The results were determined by using the following equation:

$$FC (\%) = \frac{\text{Foam volume}}{\text{Initial sample}} \times 100$$



CHAPTER 4

RESULT AND DISCUSSION

Introduction

In the chapter, the results from analysis of nutritional are presented and discussed. The effects of the maltodextrin concentration used was first discussed and analysed. Then, the nutrition content, physiochemical and functional properties of eel protein powder were discussed based on the effect of maltodextrin concentration and drying method.

4.1 Effects of maltodextrin concentration on process yield and powder condition

Table 4.1 shows the process yield, feed flow rate and powder conditions of the different maltodextrin eel protein powder produced by using spray drying method at constant inlet temperature of 160°C. From the total of 2000 g of eels (*Monopterus Albus*), 143.605 g of powder was produced for powder at 100% (w/w) maltodextrin concentration. Meanwhile, 6000 g of eels (*Monopterus Albus*) was used to produce 130.041g of powder at 25% (w/w) maltodextrin concentration.

Table 4.1: The process yield, outlet temperature, feed flow rate and powder conditions of EPP with different maltodextrin concentration under constant temperature (160°C)

Maltodextrin Concentration (%)	Process Yield (%)	Powder Conditions
25	2.17	Fine and soft powder with pale brown colour
100	7.18	Sticky powder with white colour



Figure 4.1: The graph of yield of powder of EPP at different maltodextrin concentration with constant inlet temperature (160°C)

$$\% \text{ Yield: } \frac{\text{Weight of protein powder (g)}}{\text{Raw material (wet weight)(g)}} \times 100\%$$

By using the equation above, the percentage of yielded powder produced with maltodextrin concentrations of 100% (w/w) and 25% (w/w) were 7.18 % and 3.25 % respectively. Maltodextrin act as coat to absorb the water and create the protective barrier on the surface, as well as raise the glass transition temperature of the particles (Valenzuela & Aguilera, 2015). According to Goula & Adampoulos (2008), increasing the amount of

maltodextrin in a product increases the amount of feed solids recovered. This is due to the properties of maltodextrin to raise the overall solid content of the feed. This in turn reduces the moisture content of the feed and prevent the feed from sticking to the glass of drying chamber. Therefore, the utilization of maltodextrin as drying aid will increase the yield of powder since less powder was loss to the surface of drying chamber (Quek et al., 2007).

The yield of eel powder for powder with 100% (w/w) maltodextrin (7.18%) is significant to those (3.1- 7.1%) reported by Sathivel et.al (2004). However, the lower yield of powder for feed with 25% (w/w) maltodextrin is observed. The difference in the value of fish powder yield was due to the type of raw material, drying method and processing conditions (Shaviklo et al., 2010). The reduced of powder yield during spray drying process also due to the result of small batch drying, especially for larger storage of spray drier (de Paris et al., 2016).

When 25% (w/w) maltodextrin was added to the soluble liquid protein of *Monopterus Albus*, the colour of powder was a pale brown colour, and the texture was soft. Meanwhile, the powders formed at 100% (w/w) maltodextrin had a brighter white colour with a soft and sticky consistency of powders. According to Phisut (2012), the sticky powder was formed due to a high volume of maltodextrin usage that more than 10% w/w. This is due to the texture of maltodextrin, which was highly sticky to act as a suitable binder with other materials. Several researchers reported that the spray-dried fish protein hydrolysate powder was light brown with fish-and dry squid-like odour and diluted fish sauce-like taste (Nilsang et al., 2005).

4.2 The Analysis of Soluble Protein Powder of Eel (*Monopterus Albus*)

4.2.1 Nutritional values

The composition of *Monopterus Albus* powders with 25% maltodextrin consisted of 8.6g/100g moisture, 4.4g/100g protein, 0.2g/100g lipid and 0.4g/100g ash. Meanwhile, the powder with 100% maltodextrin consisted of 8.5g/100g moisture, 0.7g/100g protein, <0.1 g/100g lipid and 0.2g/100g ash. From table 4.2, the moisture, protein, lipid and ash contents tended to reduce with increasing the maltodextrin concentration. There was no significant difference in powder lipid and ash content at 25% and 100% maltodextrin concentration.

Table 4.2: The Proximate Composition of FPP powder with different maltodextrin concentration under constant temperature (160°C)

Component	FPP, 100% maltodextrin concentration (g/100 g)	FPP, 25% maltodextrin concentration (g/100 g)
Ash	0.2	0.4
Moisture	8.5	8.6
Protein	0.7	4.4
Fat	<0.1	0.2
Carbohydrate	90.6	86.4

The moisture content of eel powder was reduced as the increased of maltodextrin concentration. When the maltodextrin concentration is increased in the feed, the total solids also increase. Therefore, the increase of total solid in meals will reduce the evaporation rate and causes the moisture contents of the powder to drop (Abadio *et al.*, 2004). The water content of the sample fed into the spray dryer process will affect the

final moisture content of the powder (Kanpairo et al., 2012). The present findings were in agreement with the results obtained for spray dried tomato powder (Ramos et al., 2016), orange juice powder (Santiago et al., 2016), cactus pear juice powder (Rodriguez-Hernandez et al., 2005), black carrot powder (Dellacassa et al., 2017) and gac juice powder (Vladić et al., 2016).

Among the samples, the protein of powder with 25% maltodextrin is higher (4.4g/100g) than powder with 100% maltodextrin (0.7g/100g). The difference is because, at 25% maltodextrin, the quality of powder in terms of the characteristics and nutritional value of the powder was preserved (Chng et al., 2020). When compared to soluble protein powder produced from tuna precooking juice (28.49 g/100g), saithe (74.5 g/100g) reported by Kanpairo et al. (2012) and Shaviklo et al. (2010) respectively, the protein content was different compared to this study. Meyerzon (2012) and Janine (2011) indicated that extremely high temperatures over an extended period might diminish protein content in food due to protein denaturation. The raw material, drying technique, and processing method also contributed to the variation in the value of protein content in fish protein powder (Shaviklo et al., 2010).

Furthermore, the lower protein content of soluble eel protein powder was observed when the results was compared with soluble protein powder of Alaska pollock that contain 67.5 g/100g crude protein content. In this study, the lower protein content obtained is possibly because the protein was aggregated during spray-dried prior to separation of the soluble protein. Additionally, different tissues have varying concentrations of certain proteins. In this study, the part of fish used is the fillet while head part was used for Alaska pollock protein powder. Therefore, each part would contribute to the significant amount

of protein. According to reports, fish muscle needs to be blended with 0.5 to 1.0 M neutral salt solutions to extract 85–95 percent of the protein present in fish muscle (Dyer et al., 1950). Lower extraction yields were obtained in this investigation because protein was extracted from the fish tissues using water and subsequently heated.

Moreover, up to 70% of whey protein may denature during the spray drying due to the high temperature used to concentrate the liquid into solid forms (Anandharamakrishnan et al., 2007). According to A. R. Shaviklo (2015), fish flesh showed significantly higher protein content than the fish protein powder (FPP). However, when using these substances (maltodextrin) as drying adjuvants, care must be taken. They primarily consist of high molecular weight carbs; if added in excess to the dried liquid, they may severely affect the resulting protein (de Paris et al., 2016).

Refer to table 4.2, the concentration of carbohydrate was highest in powdered samples at 100% maltodextrin (90.6g/100g) followed by 86.4 g/100g in samples at 25% maltodextrin concentration. Maltodextrin is a carbohydrate-additive used during spray-drying process to boost the glass transition temperature by adding the large molecular weight into the particles. As a result, the increased maltodextrin addition raises the amount of carbohydrates in the soluble protein powder. Since the carbohydrate is not a filler, making protein powder with it is not detrimental. Your daily calorie intake should consist of 45 to 65 percent of carbs, according to the Mayo Clinic. However, it is recommended that those with diabetes or celiac disease refrain from consuming foods rich in carbohydrates and instead choose for healthier alternatives.

Figure 4.3 shows that the vitamin C content of FPP powder at 25% (w/w) maltodextrin was higher as much as 3.6 times compared to powder at 100% (w/w)

maltodextrin, which was 14.5 mg/ml and 4.14 mg/ml. The lower vitamin C percentage for eel powder at 100% additives concentration is due to the increased maltodextrin. Phan et al. (2021) explained that adding maltodextrin in the processing of *Terminalia ferdinandiana* fruit powder reduced the percentage of vitamin C from 8.1% to 3.3%). The findings obtained indicate that maltodextrin addition at 10-15% is suitable and efficient in limiting vitamin C losses during drying. These findings are in good agreement with past research by Sidlagatta et al. (2020) on the spray-dried sweet orange juice that lower input air temperatures and lower maltodextrin concentrations resulted in more excellent vitamin C absorption.

Table 4.3: The vitamin C FPP powder with different maltodextrin concentration under constant temperature (160°C)

Concentration of Maltodextrin (%)	Weight of vitamins in samples (mg/ml)
25	14.5
100	4.14

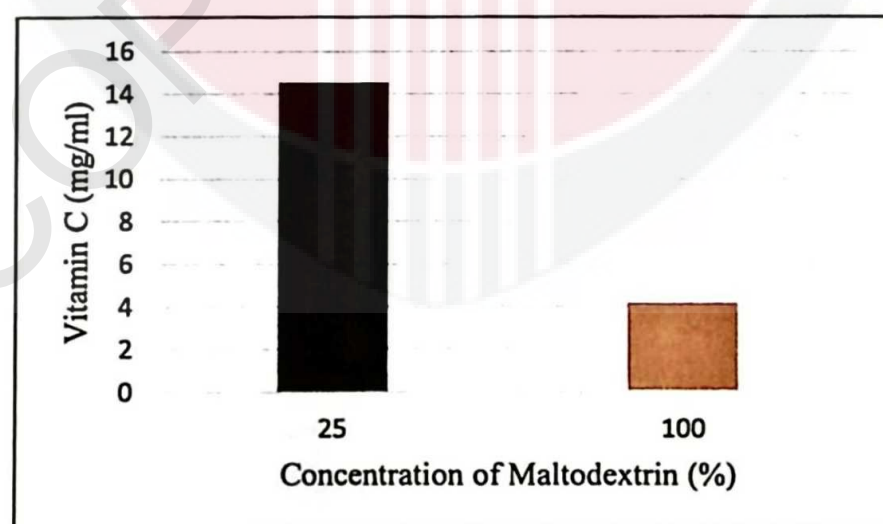


Figure 4.2: The graph of vitamin C of soluble protein powder of eel

Furthermore, vitamin C is very sensitive to heat and the degradation of vitamin C during food processing is likely to occur (Lee et al., 2018). Therefore, the high temperature of the spray dryer might diminish the vitamin C content in eel powder. Then, since vitamin C is especially vulnerable to oxidation and leakage into water-soluble media during storage, it is usually used as a proxy for the overall amount of nutrients retained in meals (Davey et al., 2000). After harvest, it begins to deteriorate and continues to do so while being stored (Murcia et al., 2000). So, protecting the eel powder from light and oxidation while in storage might stop the vitamin C from continuously degrading over time.

The essential amino acids lysine, methionine, cystine, threonine, and tryptophan are abundant in fish protein, which is a vital source of nutrition (Mohany et al., 2014). The essential and non-essential amino acids, which the body cannot make and can, respectively, aid in the growth and normal functioning of the human body. It plays a crucial part as a flavor and taste component and is crucial for fish metabolism. This methodology of study made it possible to analyze seventeen amino acids. The values of the amino acid compositions in *Monopterus Albus* were given as g/100 g fish samples are presented in Table 4.4. According to the findings, phenylalanine (2.08 mg/1 g), which is an essential amino acid, and glutamic acid (1.74 mg/1 g), which is a non-essential amino acid, have the greatest amino acid concentrations in the body. Valine (1.05 mg/g), leucine (1.14 mg/g), and lysine (1.68 mg/g) are other prominent essential amino acids, whilst glycine (1.15 mg/g) and proline (1.85 mg/g) are prominent non-essential amino acids. More than 1 mg or 1 percent of the samples include these amino acids. Less than 1% of the sample from 100 g were also discovered.

These amino acids are well recognised for playing significant functions. The inflammatory cells in the wound use glutamic acid for energy and to promote growth (De Bandt and Cynober, 2006). Glutamate is used by fibroblasts to create proteins and nucleic acids. According to De Bandt and Cynober (2006), glycine is a crucial part of collagen, whereas arginine is necessary for immune system and wound healing. High composition of phenylalanine helps with the production of the pigment melanin, which gives color to the skin, hair, and eyes.

Table 4.4: The composition of Amino Acid in *Monopterus Albus*

Type of amino acid	Amino acid content (mg/1g extract)
	Spray dried
Histidine	0.68
Threonine	0.40
Valine	1.05
Methionine	nd
Isoleusine	0.08
Leusine	1.14
Phenylalanine	2.08
Lysine	1.68
Total essentials (E)	7.11
Hydroxyproline	nd
Aspartic acid	0.50
Glutamic acid	1.74
Serine	0.85
Glycine	1.15
Arginine	0.98
Alanine	0.58
Proline	1.85
Thyrosine	0.38
Total non-essentials (NE)	8.03
TOTAL	15.14
E/NE	0.47

These findings are in good agreement with previous study conducted by Haryati et al. (2019) and Sathivel et al. (2011) where glutamic acid was the most abundant amino acid in fish protein powder of catfish (*Clarias sp*). Eel powder thus has the potential to be employed as a culinary additive, particularly as an umami flavour enhancer, since the greatest glutamic acid level suggests that this product may be used as a fish enhancer. The crucial metabolic process known as transamination depends on glutamic acid. The amino acids arginine, cysteine, leucine, methionine, tryptophan, tyrosine, aspartate, glutamic acid, glycine, proline, and taurine are also included as functional amino acids (FAA), along with glutamic acid.

However, the total of amino acid in spray-dried soluble protein of eel was lowered (15.14 mg/1g) when compared with the previous study by Sathivel et al. (2012) on freeze-dried arrowtooth flounder fillet (AFP) protein powder (948.8 mg/1 g). High total amino acid content in comparison to this research since AFP shown how low temperature drying processing may enhance the amino acid content in protein powder products. It seems that heat treatment applied in spray drying destruct the overall amino acid content (Chasanah et al., 2019). Heat processing was reported to reduce protein value as well as amino acid by destroying or making them unavailable. Amino acids are lost in the processing of catfish; the worst process is frying with palm oil at high temperature since it decreases amino acid content in the catfish processed (Wu, 2013). Heat will not alter the order of amino acids in the chain (the primary structure), because it will not effectively break the peptide bonds between them. However, heat can force the bonds between the many polypeptide chains forming the quaternary structure to break

Fatty acid could be categorized into two groups which are saturated fatty acids and unsaturated fatty acid, where the difference laid in the chemical bond. Table 4.5 shows the fatty acid contents expressed as a percentage of total fatty acids of the eel sample. A total of 15 fatty acids were found, ranging from caprylic acid (C8:0) to eicosapentaenoic acid (EPA) (C20:5n3). Eicosapentaenoic acid (EPA) (C20:5n3), arachidic acid, and palmitic acid are the three most abundant fatty acids in the body of the eel (C20:0). For both raw (original paste) and spray-dried powder, palmitic acid predominated, followed by arachidic and pentadecanoic acid for raw eel.

When used in cosmetic products, these fatty acids have advantageous physiological benefits (topical application). Shampoo, soap, and soft cream all include the raw ingredient palmitic acid (Sajna et al. 2015). Various animal items, such as meat and dairy, as well as palm and coconut oils, also contain palmitic acid. The World Health Organization (WHO) claims that palmitic acid increases LDL levels more than other saturated fats like stearic acid. According to them, there is compelling evidence that increased palmitic acid consumption increases the risk of cardiovascular disease.

Table 4.5: Fatty Acid Composition of raw and spray-dried *Monopterus Albus*

Fatty acids	(Expressed as % of the total fatty acids)	
	Raw (initial paste)	Spray dried
C8:0 (Caprylic)	0.95	nd
C10:0 (Capric)	0.85	nd
C12:0 (Lauric)	8.37	nd
C14:0 (Myristic)	5.09	3.08
C15:0 (Pentadecanoic)	8.62	nd
C16:0 (Palmitic)	14.80	18.90
C18:0 (Stearic)	4.29	8.92
C20:0 (Arachidic)	8.96	nd
C24:0 (Lignoceric)	5.18	nd

Total	57.10	30.90
C15:1 Cis-10-(Pentadecenoic)	1.64	nd
C17:1 Cis-10-(Heptadecenoic)	5.08	nd
C18:1n9c (Oleic)	8.56	7.60
C24:1 (Nervonic)	9.13	8.63
Total	24.40	16.23
C18:3n3 (α-Linoleic)	6.81	2.53
C20:5n3 (EPA)		
Cis-5,8,11,14,17- (Eicosapentaenoic)	11.71	10.53
Total	18.51	13.06

nd = not detected

In the pharmaceutical business, eel-derived arachidic acid is often used to heal muscle tissue and to encourage muscular development (Talima & El Ridi, 2017). In raw (initial paste) and spray-dried powder, nerveonic acid (9.13 percent) was the predominant monounsaturated fatty acid (MUFA) found (8.63 %). It is possible to cure problems like schizophrenia, psychosis, peroxisomal disorders, diabetes, alcoholism, and other conditions using nervonic acid, which may also help to regenerate neuron cells and repair damaged brain nerve pathways (Akoh and Moussata, 2001, Bettger et al., 2001, Evans et al., 2003).

Eicosapentaenoic acid (EPA), which is a polyunsaturated fatty acid (PUFA), was also the main fatty acid composition in both the raw (original paste) and spray-dried powder forms. The percentages of EPA in raw (initial paste) and spray-dried powder, 11.71 and 10.53 percent, respectively, were greater. The benefits of having a high EPA intake for some heart-related disorders include treating or preventing heart attacks, clearing up coronary artery disease, and lowering triglyceride levels in those with very high levels (Etherton.K, 2005). It is also reported that the level of EPA increased according to size of fish (Endinneau & Tan, 1993, Gomez et al., 2021). Omega 3 and omega 6 fatty

acid which linoleic acid (C18:3n-3), eicosapentaenoic acid or EPA (C20:5, n-3) are the most beneficial fatty acids and were dominated in fish fat (Razak et al., 2001). These fatty acids were crucial for the process of healing wounds because whereas omega-3 is needed to reduce prostaglandin production, omega-6 is necessary for its synthesis (Calder, 2005).

The amount of processing time increased the rate of oxidation of complex unsaturated fatty acids, which is why EPA levels have reduced. Because it was so readily oxidised by air and light, EPA will eventually degrade (Barrow et al. 2009). In general, the eel fatty acids investigated in this research had a larger percentage of saturated than unsaturated acids. However, differences in concentrations and amount of minerals among fish may be due to fish diet and breeding environmental conditions, such as temperature and pH, size, age as highlighted by Gomez and Martinez (2021).

4.2.2 Physiochemical Properties

The colour of dried food is an essential parameter in determining the approval of consumers on the food products (Ali et al., 2017). From table 4.6, the lightness (L^*), redness (a^*), yellowness (b^*) and whiteness of eel powders were shown. The negative measurement for a^* value is the indicator of the greenish colour of the powder. In contrast, the positive b^* value indicates the powder was adapted to be more yellow in physical appearance rather than blue (Cie, 2016). For a^* value of the eel protein powder (EPP) powder, the a^* value slightly decreased with increasing maltodextrin concentration, while the yellowness (b^* value) increased significantly.

Table 4.6: The color of soluble protein powder of eel

Concentration of Maltodextrin (%)	L^*	a^*	b^*
25	96.97	-0.06	5.32
100	100.00	-0.08	2.14

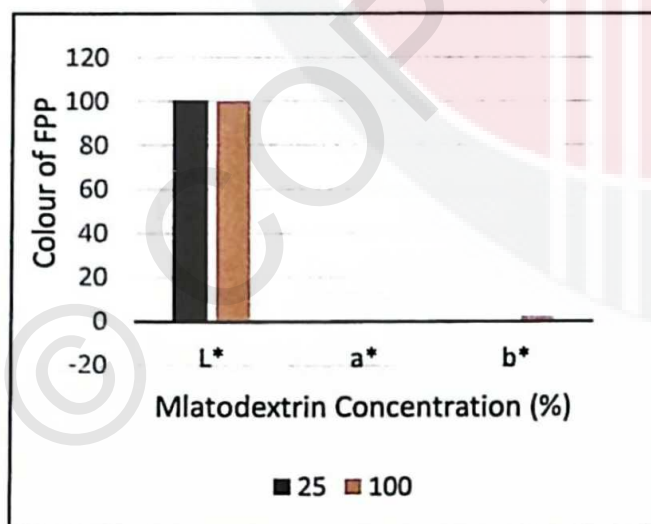


Figure 4.3: The graph of color of soluble protein powder of eel

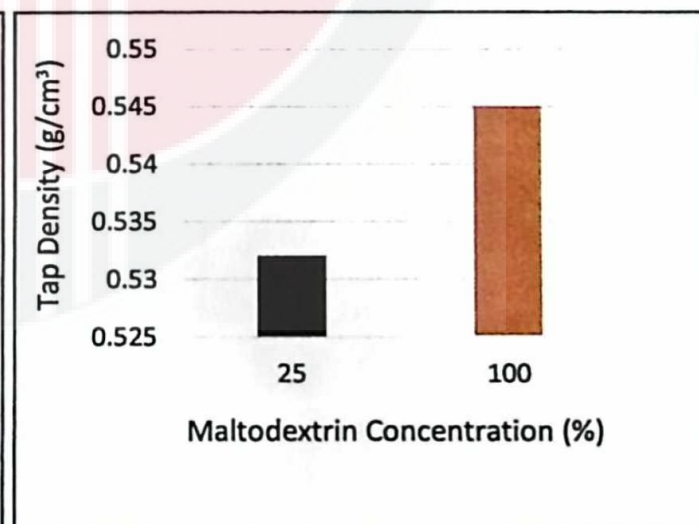


Figure 4.4: The graph of tap density of soluble protein powder of eel

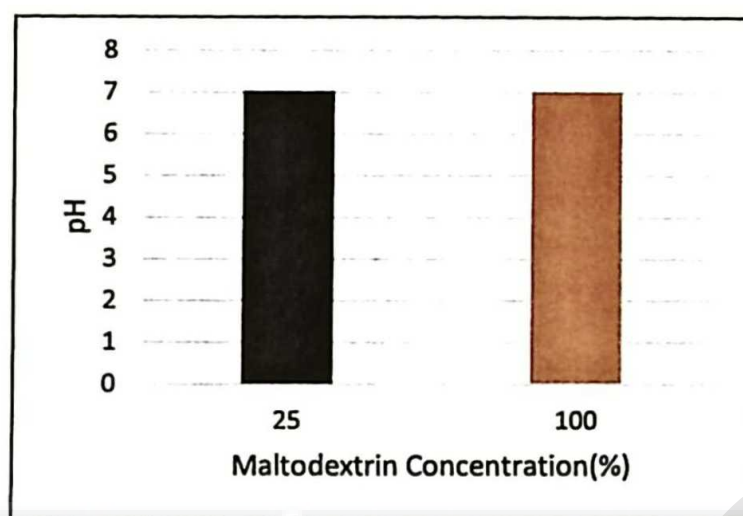


Figure 4.5: The graph of pH of soluble protein powder of eel

The L^* value for eel powder at 25% was lower compared to 100% maltodextrin concentration which was 96.97 and 100, respectively. According to Chng et al. (2020), when 100 value was measured for the L^* value for the particles, the reading indicated that the powder was very light in colour. The light colour of the powder is influenced by the colour of maltodextrin, which is white. Therefore, the powder with a high maltodextrin concentration would increase the L^* value (Kanpairo et al., 2012). This finding was similar to the study by Kha *et al.* (2010) and Mishra *et al.* (2013), where the utilization of maltodextrin affected the lightness of the final powder. Abadio et al. (2004) also studied that the maltodextrin with 25% concentration gave the highest value of L^* on the pineapple powder.

On the other hand, Sathivel et al. (2016) reported the colour of arrowtooth flounder powder. The study showed that the protein concentrate powder was light in colour with L^* and b^* values of 86.3 and 2.8. The difference L^* value from their study is due to the different drying methods. In this study, the eel powder was dried using a spray dryer, and meanwhile, the arrowtooth flounder powder was produced with a freeze-drying process.

Therefore, there is a significant difference in terms of L^* values for both drying techniques. According to Shaviklo et al. (2010), when the spray-dried saithe protein powder colour was compared with the freeze-dried samples, it showed that the spray-dried saithe protein had the most lightness and whiteness.

The spray-dried sample was whiter and lighter than the freeze-dried FPP, probably due to the high temperature, short duration in the spray-drying procedure, and also due to crystallisation of the maltodextrin during drying (Shaviklo et al., 2010). Lipid oxidation, on the other hand, may cause browning and an unattractive appearance on the FPP. The colour of the protein powder may be affected by variables such as combining fish flesh with cryoprotectants, drying process, drying temperature, and lipid oxidation, according to the findings of this research (Belitz et al., 2009)

As shown in Figure 4.4, an increase in maltodextrin concentration leads to an increase in tap density. The results showed no significant differences ($P > 0.05$) among the samples. The density of powder at 100% (0.545 g/cm³) was slightly higher than 25% (0.532 g/cm³) maltodextrin concentration. The increase in tap density is caused by the properties of maltodextrin that act as a booster in preventing the sticking of thermoplastic particles. Therefore, the higher maltodextrin addition increased the free-flow of powder (Srinivas et al., 2018). With increase in carrier agent, tapped density increased which might be due to increase in weight of end product of the powder. Following Dayal et al. (2018), the tap density would be enhanced if the maltodextrin content was raised. These findings agree with a past study conducted by Sarochawitkasit *et al.* (2007) on pineapple juice powder. Higher maltodextrin concentrations have a tendency to clump together, occupying smaller space with larger number of particles, thus increasing tap density.

Table 4.7: The tap density and pH with different maltodextrin concentration
under constant temperature (160°C)

Concentration of Maltodextrin (%)	Tap Density (g/cm^3)	pH
25	0.532	7.01
100	0.545	7.01

The density of spray-dried FPP at 25% maltodextrin in this study also was significant when compared with a previous study by Kanpairo et al. (2012) and Abdullah et al. 2019) on tuna flavour powder (0.41 g/cm^3) and surimi soluble protein powder (0.45 g/cm^3) respectively by using spray drying method. However, when the results were compared with the density of soluble protein powder of saithe (2.4 g/cm^3) produced by Shaviklo et al. (2010) through the spray drying process, the difference was not significant. Accordingly, based on the mentioned differences in densities, it was caused by the concentration of maltodextrin used in each study. For tuna flavour powder, maltodextrin concentration of 25 was added compared to 100% for soluble protein powder of saithe.

Moreover, when the densities of *Monopterus Albus* powder in this study were compared with the density of soluble protein powder of saithe by Shaviklo et al. (2010) that utilized the freeze-drying method with maltodextrin addition, the value was not significant which was 1.7 g/cm^3 . Although the maltodextrin was added in the process of both studies, the drying process was different. This finding might explain the relationship between shrinkage and drying temperature, which may be used to compare freeze-drying and spray-drying processes. Generally, spray-drying possess high operating temperature compared to freeze-dried. As a consequence, the polymer shrinks even more at higher

drying temperatures, producing smaller holes (Rahman et al., 2002). When the drying air temperature is raised, the particles have a higher propensity to become hollow and become low in density. The former is more frequent in materials that form skin and is brought on by particle inflation-ballooning or puffing. In conclusion, the density of EPP would depend on the maltodextrin concentration and drying method.

From figure 4.5, the pH of *Monopterus Albus* powder was not affected by the addition of maltodextrin. The exact pH readings on eel powder at 25% and 100% maltodextrin concentration were observed, which was 7.01. According to Ekpong & Onsaard (2018), the increase of maltodextrin increased the pH value of tamarind powder from 3.32 to 4.21 for maltodextrin concentration at 5% and 15%, respectively. The higher inlet temperature of the spray dryer with constant maltodextrin concentration also influenced the high value of pH.

4.2.3 Functional Properties

In addition to nutritional qualities, functional characteristics affect the suitability of food ingredients for usage in food industries product. The management of the water-binding capacity is a crucial factor in producing meat products of the highest quality. The protein should be able to absorb the water during food processing. The nature of hydration, solubility, viscosity, gelation, and product development will be determined by how food protein interacts with water (Haryati et al., 2019).

Referring to figure 4.6, the water binding capacity for EPP powder at 25% is lower than the powder at 100% maltodextrin concentration. The reason for this is that when maltodextrin levels rise to 100%, their hygroscopicity also tends to increase. The capacity

of a powder to binding with water from an environment with suitable humidity levels is known as hygroscopicity, and it is linked to the permeability of maltodextrin to moisture (Roos, 2002). Regarding the density of EPP, it was clear that soluble powder at a concentration of 100 had more porosity than the concentration of 25% maltodextrin; this suggests that this porosity may have caused increased hygroscopicity in this research. As a result, as has been noted by earlier researchers, both the spray-drying procedure and the lack of maltodextrin in the samples decreased the water-binding capacity of EPP (Shaviklo et al., 2010).

The additives, maltodextrin, could form an outer layer of the drops and alter the surface stickiness of particles due to the transformation into a glassy state. The changes in surface stickiness reduce the particle–particle cohesion resulting in less agglomeration, and therefore, higher water holding capacity of the powders. Increased maltodextrin concentration led to a slight increase in the ability of the powder to holding the water, which raises the moisture content of the powder. Because liquid may more readily enter the pores of agglomerated powders due to their increased moisture content, they may have better wetting properties (Buffo et al., 2002). Maltodextrin may bind to water to prevent oxidation or denaturation of nutrients on the surface of particles (Valenzuela & Aguilera, 2015). Therefore, the holding power capacity increases as the maltodextrin concentration in the EPP increases.

Table 4.8: The water binding capacity, protein solubility and foaming capacity of FPP powder with different maltodextrin concentration under constant temperature (160°C)

Concentration (%)	Water Binding Capacity (%)	Protein Solubility (%)	Foaming Capacity (%)
25	15.40	63.29	126
100	21.2	84.54	108

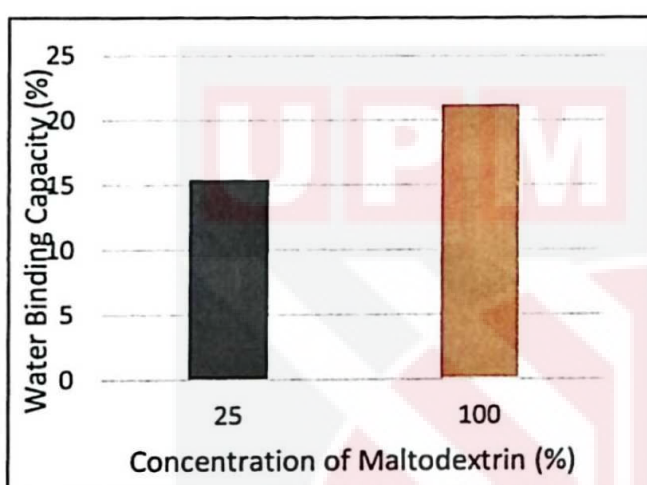


Figure 4.6: The graph of water binding capacity of soluble protein powder of eel

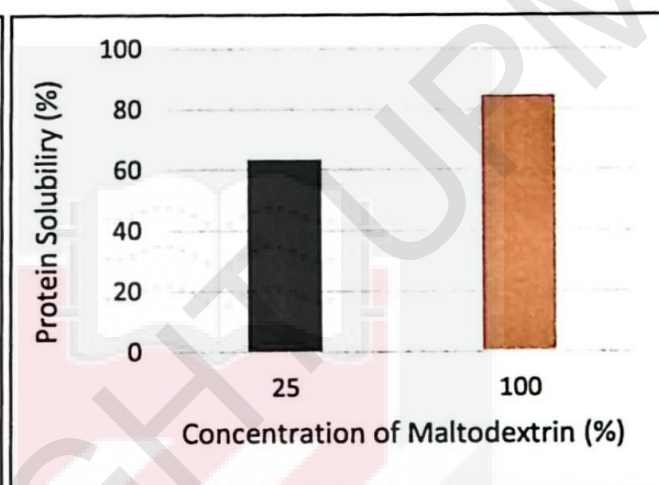


Figure 4.7: The graph of protein solubility of soluble protein powder of eel

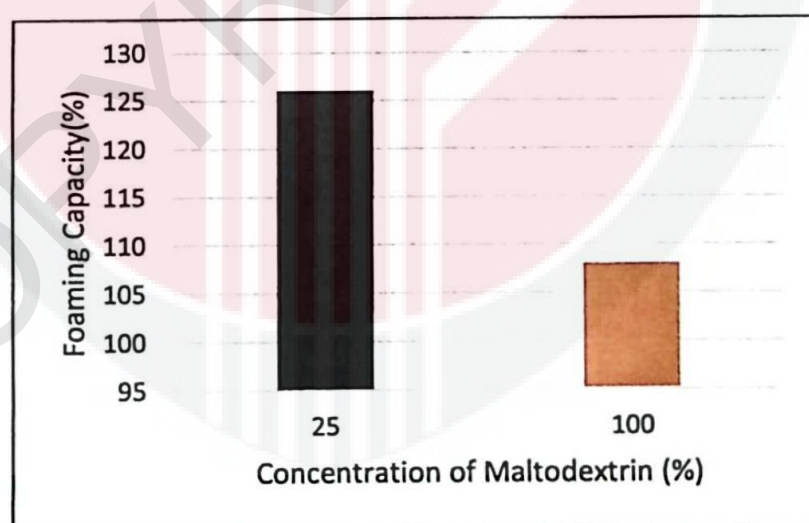


Figure 4.8: The graph of foaming capacity of soluble protein powder of eel

Rahman et al. (2002) reported that water-binding capacity of dried surimi soluble protein powder was 20% by using spray-drying. The findings were significant with this study for the soluble protein powder of *Monopterus Albus* at 100% maltodextrin concentration. However, when the results from this study were compared with the water-binding capacity of soluble protein powder of Alaska pollack (400%) and soluble protein powder of saithe (320%) by Niki et al. (2001) and Shaviklo et al. (2010), respectively, the value of water binding capacity obtained for this study is deficient even though, all samples were dried through spray-drying method. This is due to the different percentages and additives used for each process, and other additives would affect the properties of FPP (Huda et al., 2001).

Huda et al. (2001) reported that the ability of water to keep moisture may be reduced at higher drying temperatures. This could be because exposure to high drying temperatures causes denaturation of proteins. To maintain the structure of the proteins during drying, additives, including maltodextrin, have protective effects on proteins via a preferential hydration action (Haryati et al., 2019). From previous research that the relationship between water holding capacity and fish species, the quantity of maltodextrin, various drying methods and processes, and the interactions between these parameters are related. (Rahman et al., 2002)

Figure 4.7 presents the solubility of soluble protein powder of *Monopterus Albus* in water. Solubility is one of the most essential physicochemical and functional properties of protein (Kinsella, 1976; Mahmoud et al., 1992). The protein solubility of powder at 25% (63.29 %) maltodextrin was lower than powder produced by 100% (84.54%) maltodextrin concentration. The higher protein solubility for powder at 100%

maltodextrin concentration is due to the increase of maltodextrin used. This data is also following Sarochawitkasit *et al.* (2007), who reported on the solubility of dried tuna. They observed that adding 37–43% maltodextrin increased the solubility of spray-dried pineapple juice by 93%–96%. Cano-Chauca *et al.* (2005) also explained that the likelihood of solubility of powder to increase in water with the utilization of other types of maltodextrins would also exist.

Maltodextrin likely has a hydrophilic property, which improves the solubility of powder in the water. Eel protein powder (EPP) with higher maltodextrin concentration can be entirely dissolved in a solvent with the supply of thermal energy. The intermolecular forces and bonds of stabilized powder, especially hydrogen bonds, able to break down with the application of heat. As a consequence, it was possible to dissolve the soluble protein powder easily. The production of low molecular weight peptides, which contained more polar residues than the parent proteins, was another factor in the high solubility of soluble protein powder at high maltodextrin concentration. The hydrolysate powder was more likely to be more soluble in water due to its improved capacity to form hydrogen bonds with water than concentrated powder (Gimenez *et al.* 2009).

Based on the report by Hoyle & Merritt (2000), the protein solubility of herring muscle protein powder was higher (89.7% to 93.1%) than those of FPP samples in this study. Smaller peptides with more polar residues available to form hydrogen bonds with water cause enhanced solubility in herring muscle protein powder. Other than that, the difference part of fish body used in the study also contribute to the percentage of protein solubility. For herring muscle protein powder, the part of body used was the whole fish but, in this study, eel fillet was utilized. Heads, frames and trimming would all be expected

to contain substantial amounts of muscle and some of the contractile proteins appear in the soluble fraction (Sathivel & Bechtel, 2006). In addition, Sathivel et al. (2017) on the study of freeze-dried arrowtooth flounder powder, the protein solubility obtained was higher (87%) compared to this study. The difference is probably due to the high temperature implied during the spray-drying process, which reduces the amount of protein content by protein denaturation.

Foaming properties, or the shape and formation of surfaces in foams, are influenced by the concentration and properties of the proteins in the solution. Proteins create a network at the air/water interfaces as a result of intermolecular interactions, which helps to stabilize the foam system. From figure 4.9, the foaming capacity of EPP powder at 100% (108%) maltodextrin is lower than 25% (126%) maltodextrin concentration. This study observed a decrease in overrunning when the maltodextrin level increase. It was more challenging to absorb air, and the diffusion of protein and the interface was slowed down by an increased aqueous phase viscosity brought on by a rise in maltodextrin concentration (Lau and Dickinson 2005).

Additionally, the dispersion of tiny bubbles became more consistent when higher maltodextrin concentration was utilized. Maltodextrin is one of the units in dextrose, has a limited foaming extension, which prevents it from exhibiting surface activities. However, it is very hydrophilic and helps to sustain aqueous phase characteristics (Munawar et al., n.d.). Consequently, EPP powder with a high maltodextrin content has more small bubbles due to the more excellent stability of the dense medium.

According to Shaviklo et al. (2010), the foaming capacity of soluble protein powder of saithe with the addition of maltodextrin was higher for spray-dried powder (200%) compared to freeze-dried powder (190%). The difference is due to the high operating temperature of spray dryer, which causes more proteins to unfold, increasing the surface activity of powder. Foaming properties are greatly influenced by protein concentration, pH, salt, sugar, lipids and the method used for foam formation. Proteins are stabilized by creating a flexible, cohesive layer over the gas bubbles during foam formation. Accordingly, the stability of foam depends on the strength of the protein film and its permeability to gases. The highly stable foam from freeze-dried saithe may be related to its highly stable protein films, indicating that high temperature of drying affects the foaming of EPP. However, although protein may have great foamability, it may not always result in regular foam, and the opposite may also be true.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This work aimed to study the effects of maltodextrin concentration on the properties of spray-dried eel (*Monopterus Albus*) powder at the inlet temperature of the spray drier of 160°C. Increasing the maltodextrin content to 100% increased L*(lightness), a decrease in a* (redness) and b*(yellowness), and the increase in tap density during constant value for pH. The protein content and powder vitamin C at 25% were higher than 100% maltodextrin concentration. From the results, the highest amino acid contents in body are phenylalanine (2.08 mg/1g) and glutamic acid (1.74 mg/1 g), for essential and non-essential amino acids respectively. These acids are beneficial for skins health such as pH balance, skin hydration, skin firmness (anti-aging), skin repair, wound healing and as antioxidant. Meanwhile, for the fatty acid, the dominant fatty acids in eel's body are saturated fat with the highest content of palmitic acid in both raw and spray-dried powder. The functional properties of water binding capacity and protein solubility was increased while foaming capacity decreased with the increase of maltodextrin concentration. The powder obtained at a higher maltodextrin concentration has a higher yield of 7.18% due to the significant effect of drying aid during spray drying. In conclusion, the eel protein

powder (EPP) formed at a maltodextrin concentration of 25% is more favourable due to optimum properties, functionality and morphology of the powder compared to EPP at 100% maltodextrin. However, these properties were affected by the drying conditions. Some disadvantages of spray-dried eel powder are its shallow protein content compared to other FPP. Protein denaturation during drying might be prevented by preparing eel powder at a low temperature and adding a sufficient amount of maltodextrin.

5.2 Future Work Recommendation

Based on this study, some recommendations and advancements can be suggested. The recommendations are:

- 1) One should study the effect of various parameters during the drying process on the quality of the powder and optimize the process. The parameters include the types of additives, the concentration of additives, the inlet temperature of spray-dryer and etc.
- 2) One should investigate the potential of the protein powder to the value-added product. As example, palmitic acid is used as raw material for shampoo, soap and cream soft (Sajna et al., 2015). Lauric acid from fish is commonly used in the pharmaceutical industry as an anti-bacterial, anti-viral and anti-protozoon (Lin et al., 2017)

5.3 Limitations of the Study

Primarily, the analysis is not done on the raw sample (*Monopterus Albus* juice); therefore, the deviation of the nutritional content of the resulting powder from the raw samples cannot be justified. For example, the lower protein content of eel protein powder analysed in this study might be the lower percentage of protein in the raw sample. The justification that can be made to validate that the protein content of the raw sample (*Monopterus Albus*) is lower in the fresh flesh is due to the longer storage time of the sample in the freezer. The *Monopterus Albus* might have been stored for too long before it was used in the eel protein powder processing, which causes the nutrition to diminish.

After that, the limitation of this study is the low budget provided. The general budget required for this study ranges from a minimum of RM 424 to a maximum of RM 3000 (includes raw material, equipment and analysis services) which depends on the number of manipulating parameters selected. In this study, the manipulating variable is the concentration of maltodextrin. Therefore, the more amount of samples with different maltodextrin concentrations, the increased cost is needed to complete the project. The study can be improved by adding the parameters for the maltodextrin concentration at 50 and 75% to obtain the optimum trend for the effect of maltodextrin on the properties and nutritional content of the eel protein powder.

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