RECYCLE FOOD WASTE INTO ANIMAL FOOD (DOG)

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA
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This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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2022

DECLARATION

I hereby, declared this report entitled "Recycle Food Waste into Animal Food (Dog)" is the result of my own research except as cited in references.

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Date : 27 June 2022

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

....

(Dr. Nik Mohd Farid Bin Che Zainal Abidin)

ABSTRAK

Sejumlah besar sisa makanan yang tidak dimakan termasuklah sisa tulang ayam dijana setiap hari. Malaysia mempunyai masalah anjing liar yang besar yang biasanya memakan hampir semua jenis sisa makanan untuk terus hidup. Anjing liar mudah tertarik dengan sisa makanan terbuka kerana mereka sensitif kepada bau makanan. Hal ini boleh menyebabkan penyakit dan masalah seperti cirit-birit, muntah, tercekik, kurang selera makan, sembelit, kecederaan pada mulut, pendarahan rektum dan kematian yang paling teruk kepada anjing liar. Namun, masih kurang kajian untuk menghasilkan makanan untuk makanan anjing liar. Oleh itu, penyelidikan ini tertumpu untuk membangunkan proses pembuatan untuk mengilang semula sisa tulang ayam menjadi makanan anjing liar berdasarkan standard. Alternatif ini boleh membantu untuk mengelakkan masalah diet kepada anjing liar yang. Dalam penyelidikan ini, makanan anjing liar kering telah dihasilkan dalam bentuk biskut. Mesin dan peralatan yang digunakan dalam pembuatan makanan anjing liar ialah ketuhar pengering, ketuhar elektrik, mesin penghancur, pengisar berkelajuan tinggi, penimbang elektronik dan acuan tulang anjing. Makanan anjing liar dihasilkan mengikut urutan proses yang telah dibangunkan. Elemen penting dalam proses pembuatan ialah parameter proses termasuk suhu dan tempoh bakar, komposisi ramuan bahan mentah, pengikat dan penstabil dalam setiap sampel. Bahan mentah yang digunakan ialah sisa tulang ayam, bahan pengikat ialah kanji jagung, telur dan minyak kelapa, manakala penstabil yang digunakan ialah serbuk kunyit. Di akhir kajian ini, sampel makanan anjing liar telah dihasilkan dan diuji kepada anjing liar menggunakan pendekatan ujian pemakanan. Didapati bahawa parameter untuk mengilang semula makanan anjing terbiar daripada kitar semula sisa tulang ayam adalah pada suhu 130° selama 80 minit menggunakan komposisi 20% sisa tulang ayam, 47% tepung jagung, 20% minyak kelapa, 10% telur keseluruhan, 3% serbuk kunyit. Sampel makanan yang dihasilkan juga turut lulus eksperimen ujian pemakanan kepada anjing liar. Oleh itu, terbukti bahawa sisa tulang ayam boleh dikitar semula menjadi makanan anjing liar menggunakan parameter yang dicadangkan dalam penyelidikan ini.

ABSTRACT

Huge amount of unconsumed food waste (FW) include chicken bone waste is generated everyday including. Malaysia has a massive stray dog problem that will often eat almost any kind of waste including edible and non-edible produced by human to survive. They are easily attracted to open FW as the most important diet of a stray dog is the smell of the item. This may result in diseases and eating problem to them such as diarrhea, vomiting, choking, lack of appetite, constipation, injuries to mouth, rectal bleeding and worst-case death to the stray dogs. There is still lack of research of producing food for stray dog food. Therefore, this research is focused to develop manufacturing processes to remanufacture chicken bone waste into stray dog food based on standard. This alternative may help to avoid mentioned problems to stray dogs eating diet. In this research, dry stray dog food has been produced in the form of biscuit treats. The machines and equipment used in the stray dog food manufacturing are drying oven, electric oven, crusher machine, high speed blender, electronic scale and dog-boned mould. The stray dog food is produced according to the developed process sequence. Important element in the manufacturing process is controlled process parameters including baking temperature and duration, ingredients compositions of raw material, binders and stabilizer in each sample. The raw material used is chicken bone waste, binders used are corn starch, whole egg and coconut oil, while stabilizer used is curcumin powder. At the end of this research, stray dog food samples have been produced and tested to the stray dogs using feeding trials approach. It is found that the parameters to remanufacture the stray dog food from recycle chicken bone waste are at 130° for 80 minutes using composition of 20% chicken bone waste, 47% corn flour, 20% coconut oil, 10% whole egg, 3% curcumin powder. The produced food samples also passed feeding trials experiment to the stray dogs. Therefore, it is proven that chicken bone waste can be remanufactured into stray dog food using the suggested parameters in this research.

DEDICATION

To my beloved parents and family members,

That give me unconditional loves and support towards completing this report,

To my adored friends,

That gives me help and encouragement along this journey,

Also,

To the most important person, my supervisor,

That give me guidance, time, patience, cooperation, and understandings,

And lastly,

For those whoever pray for me towards completing this report,

Thank You So Much & God Bless You All Forever

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LIST OF ABBREVIATIONS

UK	-	United Kingdom
AD	-	Anaerobic digestion
EU	-	European Union
LCF	-	Low opportunity-cost feed
BSF	-	Black soldier fly
BSFB	-	Black soldier fly bioconversion
FW	-	Food Waste
CFLF	-	Chicken food liquid fertilizer
FLW	-	Food loss and waste
NFPC	-	Non-food parts of crops
CBW	-	Chicken bone waste
BHA	-	Butyl-hydroxytoluene
BHT	-	Butylated hydroxy toluene
PER	-	Protein Efficiency Ratio
SDAP	-	Spray-dried Animal Plasma
FSC	-	Food supply chain
NRC	-	National Research Council
NFPC	-	Non-food parts of crops
GA	-	Guaranteed analysis
AAFCO	-	Association of American Feed Control officials
FDA	-	Food and Drug Administration
SCP	-	Single cell protein
PER	-	Protein efficiency ratio
GSE	-	Grape seed extract
NDF	-	Neutral detergent fibre
NIR	-	Infrared reflectance
ADF	-	Acid Detergent fibre
ADL	-	Acid detergent lignin
NIT	-	Near-infrared transmittance

LIST OF SYMBOLS

Min	-	Minutes
G	-	Grams
°C	-	Degree Celsius
%	-	Percentage
w. b %	-	Moisture percentage
kg	-	kilogram
max	-	maximum
min	-	minimum
mg/kg	-	myasthenia gravis per kilogram
mg/dog	-	myasthenia gravis per dog
kcal/gram	-	kilocalories per gram
Nm	-	Nanometre
Mm	-	Megametre
MHz	-	Megahertz
GHz	-	Gigahertz
°F	-	Ferenheit
ME/kg.	-	Metabolizable energy per kilogram

CHAPTER 1
INTRODUCTION

In this chapter, the outline and intent of the research will be discussed. In this chapter, the contains for research background, problem statement, objectives, scopes of research, significant of the research and organization of report will be discussed.

1.1 Research Background

This research is about "Recycle Food Waste into Animal Food (Dog)" via critical review. In Malaysia, about 1.64 kg of food waste (FW) per day is generated which consist of unconsumed food waste excluded leftover food such as expired bread, rotten fruits and eggs are generated (Jereme et al., 2016). The amount of food waste is continuously generated every year and summing up at the landfills. However, according to (Theses and Abd Razak, 2017), there are several alternatives can be taken to reduce the amount of food waste. In such, the recycling of food waste into animal food is one of the alternatives to reduce food waste to go to the landfills.

Interestingly, food waste can be beneficial to animal by remanufacturing them into animal food. Animal food also known as comestibles. For example, (Jonathan Rivin, Zen Miller and Olivia Matel, 2014) stated that there is a need to use alternative sources of feed ingredients such as food waste for growing the livestock feed to save more cost. According to (Murugesan et al., 2021), food waste can be recycled into new value-added products such as compost, biogas and animal feed. Hence, that food waste has the potential to be remanufactured into dog food.

This research therefore focuses on identifying potential to be remanufactured into dog food. However, some considerations need to be taken to produce the dog food in this research. One important element in production of animal food is the additional substances such as binder and stabilizer as well for dog food production. Dog food can be in the form of dry, wet, semi-moist as well snack. Manufacturing processes using machines and equipment including drying oven, electric oven, crusher machine, high speed blender, electronic scale and dog-boned mould to produce the dog food will be developed in this research. At the end of this research, dog food samples will be produced and tested to the dogs.

1.2 Problem Statement

Hundreds of billions of kg of animal bone waste are produced each year, which is either rendered or disposed to prevent environmental issues (Kermavnar, Shannon and O'Sullivan, 2021). For instance, chicken bone waste is unavoidable waste which sum up each day in landfill as it is unable to consume by human. In today's developed world, the 'premiumization' of pet meals is the major driver of pet food development (Alexander et al., 2020). Most of dog food manufacturers are expanding focus which shift to produce higher-priced products with higher-priced ingredients for domestic and breed dogs. However, the stray dogs are left behind. As a result, stray dogs will eat almost any kind of waste including edible and non- edible produced by human to survive. The most important diet of a stray dog is smell of the item. For that reason, they are easily attracted to open food waste and when in desperate, they will often eat plastic containers or chicken bone waste that smell like food. The problem when stray dogs eat ground chicken bone waste is it may result in diseases and injuries such as diarrhea, vomiting, choking, constipation, mouth injuries and rectal bleeding which may lead death to them. According to Animal Welfare Board of India (AWBI) in consultation with RWA or Municipal Corporation, stray dogs have the right to be fed well by citizens. However, there is still lack of research in producing food for stray dogs. Therefore, an alternative to remanufacture chicken bone waste into good quality of stray dog food based on standard will be carried out in this research which could save them from starving, diseases and injuries. The opportunity to produce stray dog food from chicken bone waste is potentially high as chicken bone waste is summing up each day from various sources. Thus, the manufacturing process to remanufacture stray dog food from chicken bone waste should be developed in this research. The knowledges on dog food are required.

1.3 Objectives

The purpose of this research is to accomplish two main objectives as follow;

i. Propose the sequence of manufacturing processes to produce stray dog food from chicken bone waste.

ii. Produce dog food sample from chicken bone waste using controlled parameters based on animal food manufacturing standard adopted from regulation of American Association of Feed Control Officials (AAFCO).

1.4 Scopes

The scopes of research are as follows;

i. This research focus is to conduct a critical review of recycle food waste into animal food (dog) as to produce stray dog food.

ii. The product to be produced is for stray dogs or street dogs. However, the product can be fed to domestic and breed dog but strictly cannot be fed to other animals apart from dog.

iii. There are various types of food waste, however, for this research, the intention isto produce stray dog food by remanufacturing the chicken bone waste with additional of food additives including binders and stabilliser.

iv. The dog food could be dried-based, wet-based and semi moist-based. However, the intention for this research to produce dry-based stray dog food product in the form of biscuit treats.

v. The equipment and machine that will be used in the production of the dog food including drying oven, electric oven, crusher machine, high speed blender, electronic scale and dog-boned mould.

i. The dog food will be produced based on animal food manufacturing standard adopted from regulation of American Association of Feed Control Officials (AAFCO) using controlled process parameters.

1.5 Significant of the Research

The significant of the research are as follows;

ii. This research focus is to conduct a critical review of recycle food waste into animal food will help to reduce food waste contribution to landfills in Malaysia.

iii. Opportunity to gain new knowledge behind the experimental research by producing dog food from potential food waste using required machines and equipment.

iv. Generate new idea by developing proper sequence of manufacturing processes to produce the dog food.

v. Ability to give relevant information for better understanding of food waste to be remanufactured into dog food using proper method.

vi. The findings of this study contribute further recommendations for people to start separating food waste to be recycle as dog food.

1.6 Organizational of the Report

The organization of report of this thesis is based on Universiti Teknikal Malaysia Melaka (UTeM)'s thesis format which is based on publication of this research. Each of chapter consists of introduction, review of literatures, methods, outcomes of discussion and conclusions. The arrangement of report starts with chapter 1, follow by chapter 2,3,4 and 5.

Chapter 1 consists of problems that commenced with this research and the research objectives were clearly described in this chapter. The significance of this research and the scope of the study were also properly elaborated. Chapter 2 provides an overall review of the literature on the previous studies on the areas relating to the title of this thesis. In addition, within the chapter the study distance identified from previous studies was also clarified. Chapter 3 describes the research methodology for the planning, testing and data assortment of materials used in this analysis. Chapter 4 presents the postulated outcome, theory, or study of the research. The findings and analysis for dog analyzed and explained within this chapter via critical review. In addition, the findings were also addressed in this chapter and contribute to the purpose of this report. Chapter 5 presents the overall conclusions of the study as a whole and gives future recommendations, including the improvement of this study in the future.

1.7 Summary

As for the summary, chapter 1 consists of background of study, problem statement, objectives, scopes, significant of study, organization of report and summary. As for chapter 2 is discussion about the literature review related to the study. Chapter 3 is about research methodology while chapter 4 is about findings, analysis and discussion of the study. Finally, chapter 5 is about the recommendations and conclusions on the results.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the results of various literature reviews from the internet, journals, and books related to the topic "Recycle Food Waste into Animal Food (Dog) will be discussed. This section includes findings on the food waste overview, type of FW, food waste alternatives into animal food, animal feeding (food) security, AAFCO overview, food waste conversion technologies into animal food, food waste treatment technologies method categories, animal food preservative methods, types of dog food, common dog food ingredients, chicken bone-based dog food manufacturing, and dog food testing.

2.1 Introduction

In Malaysia, the number of food waste disposal in the landfills are increasing over time as number of households is increasing (Murugesan et al., 2021). Food waste is a subset of food loss, which refers to the removal from the FSC of food, whether processed, semi-processed, or raw that is fit for consumption or that has been allowed to spoil or expire as a result of negligence by the actor, primarily but not exclusively the final consumer at the household level (Bellù, 2018). Food waste is made up of ingredients that were meant for human consumption but were discarded, lost, deteriorated, or contaminated afterward (Girotto, Alibardi and Cossu, 2015).

Food waste is produced at every level of the food supply chain's life cycle, from agricultural production and postharvest activities to industrial processing, wholesale or retail sector, food service sector, and household consumption (Charalampopoulos, 2018). Food waste is categorized as low-opportunity-cost feed (LCF). LCF availability is determined by combining current food supply with statistics on FW and processing, as well as current grassland production (Dame-Korevaar et al., 2021). Food waste is defined as food products including drinks intended for human consumption but not ultimately marketed for human consumption by the food business under investigation, as well as inedible food portions (Garcia-Garcia et al., 2017). Food waste which included cooked rice, veggies, and poultry, were mixed at different ratios (Mahssin et al., 2021) as shown in Table 1 below.

However, currently the focus on treatment of food waste in Malaysia is only for restaurants and food industries. Though, food waste generated from households still remains main source of larger quantities of food waste generated when combined together, but facilities for households to engage in sustainable food waste management are not yet there (Jereme et al., 2016). (Mahssin et al., 2021) stated that almost 50 percent of the 31,000 tons of the solid waste produced daily in Malaysia comprised of organic kitchen waste such as leftover food as shown in Figure 1.

Table 1: FW composition for mix FW sample (Mahssin et al., 2021).

Food Waste Ratio (R: V: C)	**Food Waste Composition (%)**		
	Rice	**Vegetable**	**Chicken**
1: 1: 2	25	25	50
1: 2: 1	25	50	25
1: 2: 2	20	40	40
2: 1: 1	50	25	25
2: 1: 2	40	20	40
2: 2: 1	40	40	20

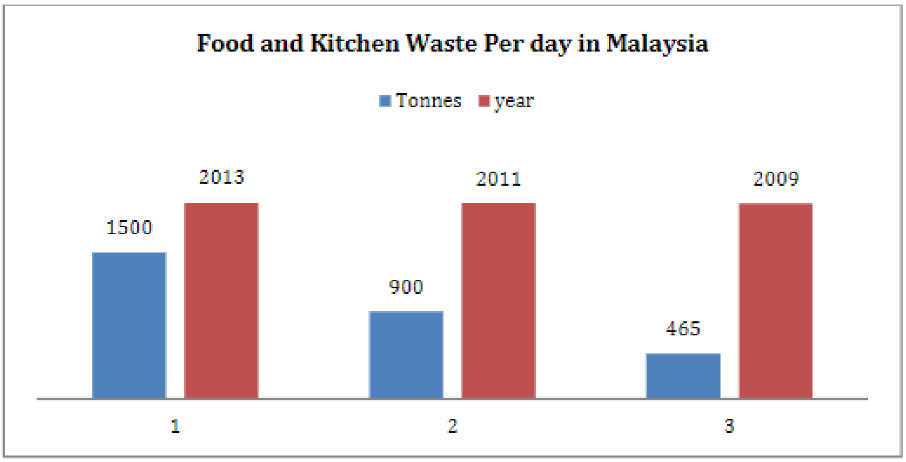


Figure 1: Food and kitchen waste per day in KL, Malaysia (Jereme et al., 2016).

Food waste contributes huge environmental problem. According to (Gligorescu et al., 2020), about 1.6 billion tons of produced food is wasted annually which lead to high environmental impacts. In such, United Kingdom (UK) disposed about 15 million tonnes of wasted food to landfill each year either by composting or anaerobic digestion (AD) method. Hence, any method should be developed to reduce FW being disposed to the landfill. One of the alternatives is by recycling the FW into animal feed (Westendorf, 2000). (Murugesan et al., 2021) also supported FW as an alternative source of animal feed has significant promise in overcoming the current catastrophic scenario of excessive cost and insufficient supply of livestock feed. According to research by (Salemdeeb et al., 2017), FW should be preferentially used as animal feed although this practice is illegal for most FW due to disease control concerns. European Union (EU) is of the country that empathizes on that matter.

Conversion of food waste into animal feed should not be a problem if the food waste is properly managed and remanufactured using hygiene and proper method. The good thing is that interest in study on potential diversion of food waste for animal feed is growing over time. For instance, many of East Asian states offering working examples of safe food waste recycling that based on tight regulation and rendering food waste safe through heat treatment. Despite the criticion towards animal-based food consumption due to its high environmental impact, upcycle low opportunity-cost feed (LCF) such as food waste, food processing by-products and grass resources into nutritious animal-source food can contribute to nutrition security. Looking into that matter, however, there is no research has yet looked into the topic regarding the allocation of livestock should be feed using LCF to maximize livestock's contribution to human nutrition (van Hal et al., 2019).

Food feed competition is challenging due to ongoing climate change, land degradation and water shortage which would affect the sustainability of food production systems (Makkar, 2018). Researchers predicted that the demand for animal product is increasing from 60% to 70% globally by 2050. It is important because additional feed will further exacerbate the food insecurity. In USA, about 21.9 million tons of food waste in solid state is generated in 1998 but only 2.4% of the food waste was recycled. However, many states in USA start to consider of collecting, processing and reuse food waste to reduce them from being disposed. In Hong Kong, food waste in solid state is the most generated waste but the action to recycle food waste is still at inception stag (Cheng and Lo, 2016). Therefore, it seems that more technologies need to develop to boost up the food waste recycling rate.

2.2 Types of Food Waste

Basically, food waste can be divided into plant-derived and animal-derived. The food waste therefore can be classified into raw, cooked and semi-cooked which are generated from many sources such as farmers to consumers. Consumers are the last level producers in food waste generation but they are also the biggest food waste producers. Food waste in physical state is classified into solid, semi-solid and liquid as shown in Figure 2 below (Murugesan et al., 2021).

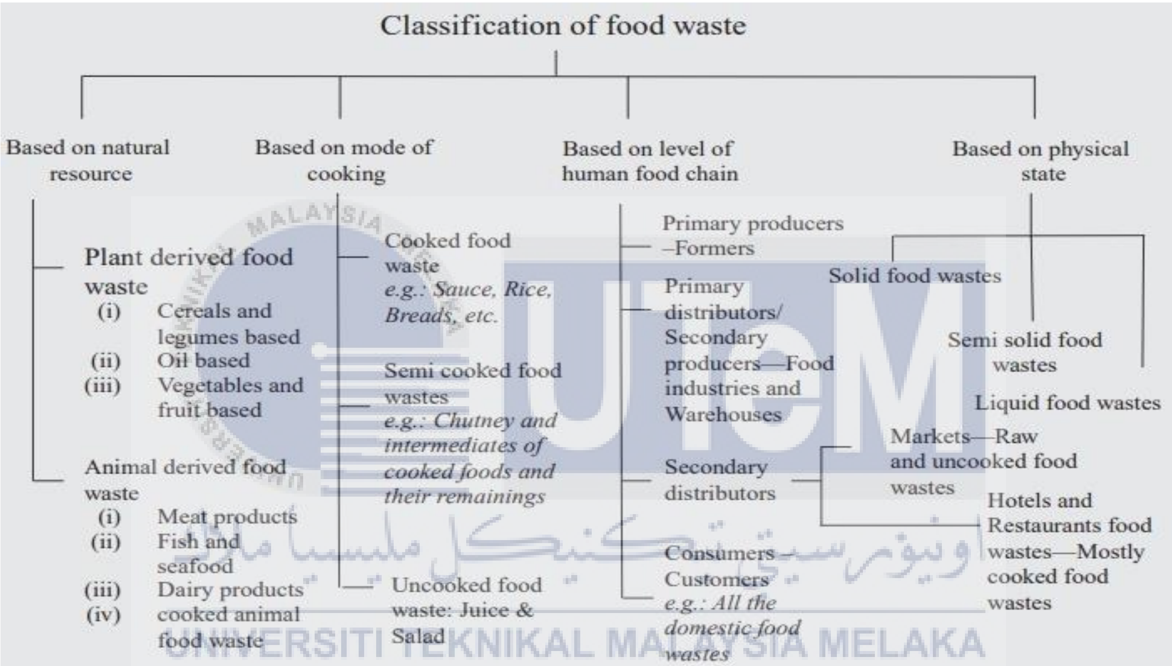


Figure 2: Classification of FW (Murugesan et al., 2021).

2.2.1 Food Waste Derived from Animals

Animal-derived food waste is waste obtained from edible animal sources. Food waste derived from animal are including meat products waste, fish and seafood, dairy products, and cooked animal. Meat product food waste includes waste such as blood, intestines, and non-edible portions of animals generated by meat processing enterprises and retail outlets. Fish and seafood wastes include the fins, gills, and scales of fish, as well as the leftovers of other marine species produced by fish markets. Dairy food wastes are spoiled milk and spillages from the dairy industry. Cooked animal-derived food waste can be considered a separate form of food waste because its nature differs substantially from the raw and uncooked food waste mentioned above. This sort of food waste includes spoiled cheese, paneer, and meat bones.

2.2.2 Food Waste Derived from Plants

Food waste derived from plants are originating from plants, such as vegetables, cereals, and grains, is known as plant-derived food waste. As a result, it's also known as vegetarian food waste (with a few exceptions like milk products). The spillage, damage, and rotting of edible plant components during harvesting, transportation, and processing events results in this food waste. Food waste derived from plants can be divided into cereal and legume-based food waste, oil-based food waste, and vegetable and fruit-based food waste. It is important to note that plant-derived substances are utilized in the preparation of animal feed, all of which must be carefully stored (Campigotto et al., 2020).

2.3 Source of Food Waste

Food waste may occur at several levels in the food chain (Campigotto et al., 2020). Food waste can be sorted into three categories. First category is food losses as food lost during preparation, processing, and production. Second category is unavoidable food wastage as spoiled food lost during the consuming phase, such as fruit peel and core. Third category is avoidable food wastage as food lost during the consumption phase such as wastage (Theses and Abd Razak, 2017). There are various sources of food waste from different types of food waste as shown in Table 1 below. In Malaysia food waste are generated from various sources such as households, commercial, restaurants, food courts, supermarkets and others from beverages industries (Jereme et al., 2016). In developed countries, more than 60% of food waste is generated in the retail, distribution, food service, and household sectors (Charalampopoulos, 2018). However, the literature reviews for this study regarding source of FW will only include households, food courts, restaurants, source separated FW and recycling totes as in Table 2. Common waste generated from household is plate waste. (Siddiqui et al., 2021) in their study stated that most of food waste and the majority of households. Food wastes are collected as part of general waste, which is either burnt or dumped. Same goes to institution, it generates commonly plate waste. As for food courts and restaurants, common waste generated is kitchen scraps and plate waste. As for food waste from separated food waste source, there is growing interest in collecting food waste as a separate waste stream and using it to make compost or recover energy through anaerobic digestion (AD) or pyrolysis (Siddiqui et al., 2021). Recycling totes also common source of food waste as many food wastes are disposed to the recycling totes daily.

Table 2: FW generated in Malaysia (Jereme et al., 2016) (Theses and Abd Razak, 2017).

Estimated Food Waste Generated in Malaysia			
Source of Food Waste	**Generation Rate**		
	(Tonnes / day)	**(Tonnes / year)**	**Percentage (%)**
Households	8745	3192494	38.32
Wet and night markets	5592	2040929	24.50
Food courts / restaurants	5319	1941608	23.35
Hotels	1568	572282	6.87
Food and beverages industries	854	311564	3.41
Shopping malls	298	108678	1.30
Hypermarkets	291	106288	1.28
Institutions	55	26962	0.32
Schools	45	21808	0.30
Fast food/chain shops	2521	808	0.26
Total	22793	8331589	100

2.4 Food Waste Alternatives into Animal Foods

It is better to recycle food wastes into valuable resources into new added-value products such as compost, biogas and animal feed compared to dispose them into the landfill (Murugesan et al., 2021). In China, research has been conducted which emphasize on safety analysis of animal feed produced from food waste using three typical treatment processes including fermentation, heat treatment and coupled hydrothermal treatment. The results obtained from the research and feedstuffs legislation found that feed derived from food waste can be considered as one of an adequate-alternative to be used in animal diets by changing the feeding action such as restrictions on the application of ruminants, and recycling as formula feeds (Chen, Jin and Shen, 2015).

Feeding strategy experiment also should be conducted to optimize feedings and decrease handling followed by a digestibility study for assessing the applicability of food waste as a feed ingredient (Gligorescu et al., 2020). It is worth it to convert food waste into feed for animals from being wasted in order to maintain the food supply chain (Makkar, 2017). According to the waste hierarchy for surplus food and food waste in Figure 3 below, animal feed is the third most preferred approach after redistribution for human consumption and prevention of food waste generation to reduce food waste (Garcia-Garcia et al., 2017). According to researcher, animal feeding is the best alternative for meals that are not fit for human eating but can be fed to animals. This alternative is being considered as concern about food safety have been addressed. Researcher said that feeding food waste to pigs and chickens poses threats to public health but feeding it to fish is considered low risk (Cheng and Lo, 2016).

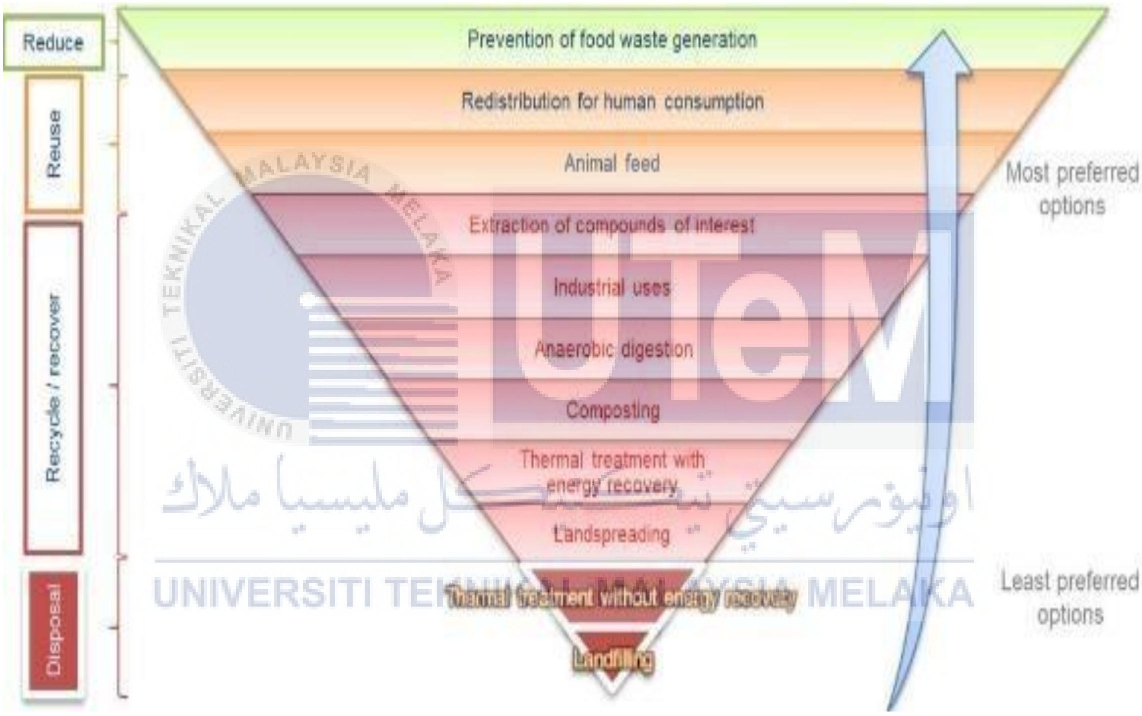


Figure 3: Waste hierarchy for surplus food and FW (Garcia-Garcia et al., 2017).

Food waste recovery for animal feeding as by means refeed is a realistic option that has the ability to address waste management of landfilling, food security, and resource and environmental concerns all at the same time (Dou, Toth and Westendorf, 2018). Using food waste in livestock feeds can help farmers save money on feed and food waste generators save money on disposal while reducing the waste's environmental impact (Jonathan Rivin, Zen Miller and Olivia Matel, 2014). Other disposal alternatives, such as anaerobic digestion, incineration, and landfill, food conversion into CFLF yielded much lower environmental credits (Siddiqui et al., 2021). (Laso et al., 2018) in their study to evaluate food waste to food strategies using nexus approach also mentioned that food waste as animal feed in aquaculture as one of the current applied alternatives apart from incineration of food waste with energy recovery and landfilling with biogas recovery food waste management.

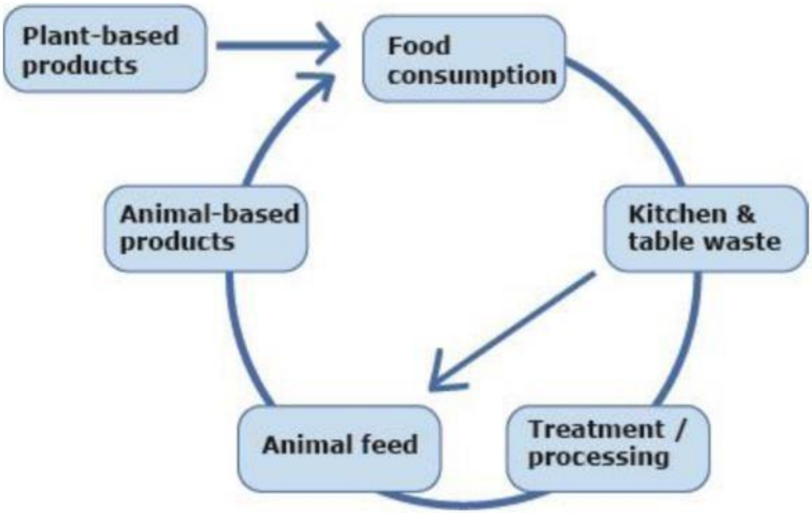


Figure 4: Food production, consumption, and processing into animal feed phases (Dame-Korevaar et al., 2021).

2.4.1 Livestock Feed

In research conducted by (Ramírez N., Peñuela S. and Pérez R., 2017), food waste can be transformed and enriched for feeding pigs with values that have been favorable for production, thus promoting environmental conservation and leading to organic production that reduce the negative impacts on natural resources and nutritional loss. Another study conducted by (Siddiqui et al., 2021) to produce chicken feed and liquid fertilizer (CFLF) by collecting foodwaste samples from service club, cafe restaurant, bakery and supermarket. Researchers said that the CFLF is used to produce chicken feed pallets which contain of 19% protein within the National Research Council (NRC) recommended range of 15 to 23%. Dried citrus pulp is used as cattle feed as it has high net energy value for lactating dairy cows (Wadhwa and Bakshi, 2013). Besides, pineapple juice waste, cut potatoes, rice hulks sundried tomato pomace, banana peel, soy hulls, cabbage waste, jackfruit waste and brewery waste also usedto feed cattle (Ajila et al., 2012). For fish feed, groundnut cake, palm kernel cake, wheat bran, rice bran, maize bran, livestock blood, and fish wastes, fruit waste, cereal waste and organic waste can use to feed the fish (Caipang, Mabuhay-Omar and Plasus, 2019). (Singh and Saxena, 2015) in theirstudy discovered that certain edible seaweeds can be feed to fish due to their low calorieand fat content, and high mineral, vitamin, and protein content.

2.4.2 Poultry Feed

Same as livestock feed, dried citrus pulp ensiled with wheat or rice straw with ratio 70:30 can be feed to the chickens. Bakery waste and cabbage wastes also can be converted into poultry feed. Bakery waste is product which exceed expiry date such as cake leftovers, pieces of toast, biscuits. In this case, bakery waste can be an alternative for poultry feed replacing maize and cereals grains. Meanwhile, cabbage waste is a good source of protein hence suitable to feed poultry (Murugesan et al., 2021). When cabbage is included in a poultry diet, body weight increases at a faster pace at 20 weeks, along with enhanced egg output (Ajila et al., 2012). Carrot waste also can used to feed the chicken as it is rich in total digestible nutrients and provide carotenoids to laying hens hence improve production of egg and colour of egg yolk (Bakshi, Wadhwa and Makkar, 2016).

2.4.3 Pet Food

Sundried tomato pomace is a good source of lycopene, which can consume by rabbits up to 20% to 30% of in their diet (Wadhwa and Bakshi, 2013). Cabbage wastes are viable rabbit food source, as rabbits fed water spinach, cauliflower leaves, cabbage, or Chinese cabbage grew faster. Rabbits who were fed with oats and fresh forage (alfalfa, clover, or cabbage) grew well. Paddy rice, sweet potato roots supplemented with water spinach-based basal diet increased animal growth rate and feed conversion efficiency (Ajila et al., 2012).

2.5 Animal Feeding (Food) Security

Animal feed production from FW has caught the attention of many countries (Murugesan et al., 2021). Guidelines have been developed for feeding alternative of FW and food by-products to cattle and swine (Jonathan Rivin, Zen Miller and Olivia Matel, 2014). (Georganas et al., 2020) published a paper to study the potential bioactive substances, molecules found in minute concentrations in foods such as fatty acids, vitamins, carotenoids, peptides, and polyphenols present in FW material for transformation of FW to animal feed. It is the hope of addressing food insecurity and providing health benefits by using FW rather than throwing it away for applications in chicken and swine nutrition. (Makkar, 2017) also supported that food loss and waste (FLW) affects food security as well as local and national economies. FLW and non-food parts of crops (NFPC) could be reintroduced to the food chain by include them in animal feed. Over the last 20 years, many of East Asian countries have implemented controlled, centralized systems for safely recycling FW into animal feed. However, efforts on addressing concerns towards food safety and disease control to consumer and farmer highly are required (zu Ermgassen et al., 2016). (Dame-Korevaar et al., 2021) stated that dangers such as non-infectious microorganisms, physical, and chemical risks, require additional attention by using good facilities and strict regulations.

2.6 Association of Feed Control Officials (AAFCO)

The Association of American Feed Control Officials (AAFCO) is responsible for developing model standards for pet foods, including labelling requirements, ingredient definitions, and nutrient criteria. AAFCO provides the analytical variances for each nutrient in guaranteed analysis (GA) to ensure that analytical variation is kept below acceptable limits, as well as to account for it and develop goods that contain enough nutrients to fulfil the GA's permissible range (Burdett, Mansilla and Shoveller, 2018). The AAFCO collaborated with FDA to guarantee that commercial pet foods are safe in which AAFCO pet food standards are designed to address the nutritious content and product label of pet meals to ensure consistent consistency and enforcement of these claims (Wilson-Frank and Hooser, 2018). Percentage of AAFCO for dog food can be seen in Table 3 below.

Table 3: Percentage of AAFCO dog food nutrients profile (Burdett, Mansilla and Shoveller, 2018).

Nutrient	Growth (%)	Maintenance (%)
Crude protein	22.5	18.0
Crude fat	8.5	5.5
Arginine	1.0	0.51
Histidine	0.44	0.19
Isoleucine	0.71	0.38
Leucine	1.29	0.68
Lysine	0.90	0.63
Phenylalanine	0.83	0.45
Phenylalanine + Tyrosine	1.30	0.74
Threonine	1.04	0.48
Valine	0.68	0.49

According to Model Regulation PF9, nutrient content stated on dry matter basis assumes caloric density of 4000 kcal metabolizable energy (ME)/kg. For inventive formulations, the energy density of 4000 kcal ME/kg must be rectified while the energy density of formulations of 4000 kcal ME/kg does not need to be modified. Low-energy density formulations should not be regarded suitable for reproductive needs based only on the profiles. The AAFCO recommends a CP need of 18% on a dry matter basis for dogs in maintenance (Burdett, Mansilla and Shoveller, 2018).

(Kritikos et al., 2018) revealed that manufacturer reported VitD3 contents as in Table 4 were correct, where the dog owners may be sure that the VitD3 consumption in AAFCO compliant commercial dog diets is acceptable. Researchers also mentioned that foods having a moisture level of more than 70% were classified as wet, while those with a moisture content of less than 10% were classified as dry. Each meal was classified according to whether it was prepared to fulfil AAFCO nutritional profiles for adult maintenance or all life phases, or whether it had gone through AAFCO feeding trials for adult maintenance or all life stages.

Table 4: VitD3 concentration of commercial dog foods summarized on basis of various categorization schemes (Kritikos et al., 2018).

Variable	**Category**	**No. of samples**	**Geometric mean(95% Cl)**
Moisture	Dry Wet	72 9	421 (371-475) 404 (270-606)
AAFCO nutritional adequacy statement	Nutrient profile–adultmaintenance Nutrient profile–all life stages Feeding trial–adult maintenance Feeding trial–all life stages	26 30 18 7	369 (307–445) 432 (362–515) 417 (318–546) 596 (377–942)
Company size	Large Small	40 16	425 (358–504) 405 (316–519)
Purchase location	Veterinary exclusive Over the counter	25 56	411 (330–512) 423 (369–484)

2.7 Food Waste Conversion Technologies into Animal Feed

Current approaches to deal with food waste have serious (Dou, Toth and Westendorf, 2018). Among the common conversion technologies of food waste into animal feeds are heat drying and black soldier fly bioconversion (BSFB) (Cheng and Lo, 2016). Food waste conversion to a value-added product like animal feed can enhance food efficiency by lowering the cost of animal feed, resulting in higher earnings for farmers and reduced environmental impacts from food waste disposal where a single cell protein (SCP) production is significant and promising method for food waste conversion into animal feed (Murugesan et al., 2021).

2.7.1 Black Soldier Fly Bioconversion (BSFB)

Black Soldier Fly Bioconversion (BSFB) required black soldier fly (BSF) for the food waste conversion into animal feed end-product. BSF also known as Hermetia illucens is defined as holometabolous Diptera specie which native to Neotropics and currently spread across the temperate and tropical regions (Surendra et al., 2020). According to (Gligorescu et al., 2020), BSFB technology is the most promising insect species for bioconversion of food waste. (Cheng and Lo, 2016) also stated that BSFB is a preferable technology for food waste conversion into animal feed as the final product in the form of insect powder able to gain import approval from mainland China. A study conducted by (Murugesan et al., 2021) revealed that BSF has the ability to consume a variety of organic wastes, including chicken feed, pig liver, pig manure, kitchen waste, fruits and vegetables, and rendered fish, with kitchen waste producing the most fly biomass. So, this technology is suitable for livestock feed conversion into animal feed. They concluded that BSFB has been identified for food waste conversion into animal food.

2.7.2 Heat Treatment

Food waste without processing and treatment can be fed to pigs in United States (US). However, due to widespread of highly transmissible viral swine illness, Vesicular exanthema in 1950s, US has introduced state regulations that require the heating of food waste products before feeding to pigs (Dou, Toth and Westendorf, 2018). Nowadays, heat treatment of food waste before feeding to animals is a worldwide requirement, however the temperature and duration vary by country and treatment technique. Appropriate heat treatments, proper facilities, and rigorous rules can eliminate many microbiological dangers in animal feed (Dame-Korevaar et al., 2021).

2.8 Food Waste Treatment Technologies Method Categories

Food waste methods categorized into three including wet-based, dry-based and ensiling or fermentation treatment (Dou, Toth and Westendorf, 2018). Different parameters are required for each of the treatment category. In other study, (Chen, Jin and Shen, 2015) reported that they presented three treatment processes related to safety analysis of animal feeds including fermentation, heat treatment and coupled hydrothermal treatment. Food waste derived feed is an adequate alternative when supplemented properly and can guarantee the bacterial inactivation (Rajeh et al., 2021).

2.8.1 Wet-based

A simple heating phase is usually included in wet-based methods to sanitize the raw waste material, making it suitable for animals. FW and food processing by-products were cooked at 100°C for 4 hours to be utilized in pig feeding studies. Sorted FW from municipal solid trash will be crushed (1 mm), homogenized, and heated at 65–80 °C for 10 minutes to 60 minutes as a potential feed. Then, the nutrients, microorganisms, and toxins were studied. Basically, wet-based feed products have a high moisture content of 70% to 80% and a limited storage life, thus they must be used near the processing plant within a short time window.

2.8.2 Dry-based

As for dry-based treatment method, it combines heating by means sterilization and drying to generate feeds that have a longer shelf life of 80% to 90% DM and are easier to handle. Food service waste was mixed with soy hulls and wheat flour, pelletized, and dried at 110°C to 120 °C in a fluidized bed drier, for example. Household food waste that has been processed through rinsing, grinding, dewatering, and vacuum dehydration. Shredding and dewatering, heat-sterilizing, additional dewatering, and drying of home and restaurant food waste to dry feed. For instance, many utilized restaurant and domestic food waste sieved to 5 mm, and dried at 115 °C in a drum dryer. Dry-based treatment is ideal to centralize facilities near urban centres as feed products can be transferred to distant animal operations.

2.8.3 Ensiling or Fermentation

When using ensiling or fermentation method, the heating-sterilization process and addition of prescribed microbial/yeast agents are required. The latter make use of easily degradable substrates, which serve to stabilize the material while still retaining nutrients. Individual study had different ensiling or fermentation procedures and circumstances. For example, a probiotic microbial mix containing yeast, lactic acid bacteria, and E. coli was used to aerobically ferment household food waste for 24 hours at 30°C to 40°C with a probiotic microbial mix containing yeast, lactic acid bacteria, and E. coli. Food waste was mixed with wheat and rice bran, as well as sawdust and beet pulp, and a microbial mixture of Ba-cillussp., yeast, and lactic acid bacteria was added, after which the materials were fermented for 4 hours to 10 hours at 60°C to 80°C, and the final product was dried to 91% DM (Chen et al., 2015). Ground restaurant food waste was aerobically fermented with a microbial culture and chicken litter at 55°C to 60°C for 4 hours, then vacuum dried. Ensiling or fermentation process extends the shelf life of the final product. After fermentation, feed made from cafeteria food waste was stable for up to 30 days.

2.9 Animal Food Preservation Method

One research has been conducted in China which emphasize on safety analysis of animal feed produced from FW using three typical treatment processes including fermentation, heat treatment and coupled hydrothermal treatment. The results obtained from the research and feedstuffs legislation found that feed derived from FW can be considered as an adequate-alternative to be used in animal diets by changing the feeding action such as restrictions on the application of ruminants, and recycling as formula feeds (Chen, Jin and Shen, 2015). A series of processing technologies are used to convert FWinto a complex animal feed to increase nutrition quality, digestibility, feeding efficiency, toxin elimination, pathogen sanitation, removal of non-edible components, long- term storage feasibility, transportability, and marketability. Dehydration or drying, pelleting, extrusion, fermentation, silage making, and other processing procedures can all be used to convert FW to animal feed. When transforming certain type of FW into an acceptable animal feed, these processing processes are either combined or used individually (Murugesan et al., 2021).

2.9.1 Dehydration

Dehydration is the process to remove water from food to prevent microbial growth and maintain food quality. Water makes up a large portion of food waste's overall biomass, which is believed to be between 80% and 90%. The increasing moisture level encourages microbial growth and enzyme activity, which results in the denaturation of food nutrients, which turns food waste into harmful chemicals. This method not only preserves the food waste, but it also reduces the weight, making it easier to pack and transport at a reasonable cost (Cohen and Yang, 1995). The National Research Council (NRC, 1998) suggested that animal feed contain between 10% and 12% moisture content (Arvanitoyannis and Kassaveti, 2008).

2.9.2 Sun Drying

Sun drying, often known as solar drying or open-air drying, is most likely the oldest industrial technique still in use today for a wide variety of food products including fruit, meat, fish, and plants. It is a common and practical way for disposing of food waste However, sun drying has limitations for a large-scale production. For instance, sun drying needs large space and significant labour inputs, difficulty in managing the rate of drying, insect infestation, and microbial contamination (Cohen and Yang, 1995). Using sun drying technique, the food waste is spread out on a surface, and the moisture is evaporated using solar heat energy. This easy approach allows for the processing of large amounts of a variety of food wastes, such as vegetables, fruits, meats, and nuts, in a shorter amount of time and with less energy. However, the difficulties to manage dehydration, the high cost of labour, and the requirement for broad regions to disseminate the materials are all limiting concerns (Murugesan et al., 2021). Hence, using this method, food deterioration and fungus are reduced when drying times are reduced (Pamela Schmutz and E. H. Hoyle, 1999).

2.9.3 Freeze Drying

Freeze drying, also known as lyophilization, is the process of removing the liquid phase of a frozen material under high vacuum. The freeze-drying technology maintains food product quality, is extremely cost-effective, and is best suited for heat-sensitive foods, as well as preventing microbiological food deterioration. Despite the advantages, this method is unsuitable for large-scale animal feed production practices.

2.9.4 Microwave Drying

Microwaves are electromagnetic waves with frequencies ranging from 300 MHz to 300 GHz and wavelengths ranging from 1mm to 1m. Microwave electromagnetic energy is turned to heat energy in this process by interacting with water molecules in the food substance. Microwave dehydration is a fast and advanced approach. However, it is also highly expensive when compared to other ways. A study conducted towards manganese ore by (Du et al., 2020) revealed that microwave drying rate increased as the particle size and micro-wave power of the manganese ore increased, which was accompanied by an improvement in the drying efficiency by employing diffusion approach model and Fick's second law.

2.9.5 Oven Drying

An oven is perfect for drying meat jerkies, fruit leathers, and banana chips on occasion, as well as keeping excess produce such as celery and mushrooms. Because there is no built-in fan for air flow, oven drying takes longer than dehydrators. A fan is included in some convection ovens. It takes twice as long and uses twice as much energy to dry food in an oven than it does in a dehydrator. When using oven, ensure reading is as low 140 °F so it dried instead of cook (Pamela Schmutz and E. H. Hoyle, 1999).

2.9.6 Silage

Silage is a fermented animal feed made from a variety of agricultural and industrial wastes. Food and agricultural wastes are collected in big hollow cylinders known as silos for the production of silage. The feedstock is fermented for about a week under anaerobic conditions, during which time carbohydrates are transformed to organic acids by microbial activity. Rice straw, wheat straw, molasses, fish, and other ingredients have been used to make various varieties of silage since ancient times. In dairy cattle diets around the world, whole plant corn silage has been the most commonly used fodder (Ferraretto, Shaver and Luck, 2018). Microbes transform organic materials like cellulose and starch into necessary volatile fatty acids during the silage fermentation process, which improves the palatability of the feed. In addition, the bacteria produce various vitamins that are necessary for animal feed throughout the silage process. Similar to the conversion of milk lactose into lactate by Lactobacilli, which preserves milk for a long time, silage production ensures long-term storage of fodder and availability of animal feed.

2.10 Additives for Animal Food Preservation

Additives are often required in animal food preservation which refer to additional ingredients or substances. The food waste that is utilized as substrate will first be collected and processed before adding substrate and other required elements such as minerals and stabilizers by and finally the pH is adjusted to promote growth and biomass. Preprocessing may include a number of stages, including the removal of unwanted wastes, grinding, and quality control (Murugesan et al., 2021). Common additives required for animal food preservations including salt, preservatives, stabilisers, and gelling agents are required (Ockerman and Hansen, 1988). Many foods that are stored at room temperature require preservatives, yet not all preservatives are harmful.

2.10.1 Binder

Binder in food are additives that are added to food products to improve texture of ingredients together by thickening and binding. There are many starches which often used as natural binder in food. One of the most common organic molecules, starch is used as a binder as it is a biodegradable binder that may be utilized in a variety of applications. However, the characteristics and qualities of starch have an impact on binder efficiency

(Mohd et al., 2016). Result from experiment conducted by (Motzer et al., 1998) revealed that water binders were added to the 100n and 50/50 treatments, improving the water holding properties of restructured ham slices. Comparison between binders in animal food can be referred as in Table 5 below.

Table 5: Comparison of binders in animal food (dog) (Burkhardt, 2019).

Binder	**Description**
Grains (corn, rice, wheat)	Rice is an example of novel protein source (Donadelli et al., 2019).
Starches (tapioca, potato, corn, pea)	Pea, and potato protein concentrates are examples of novel protein sources (Donadelli et al., 2019). Dogs digest and metabolise starcheseffectively, with differences depending on food processing factors, starch source, and dog breed. Starches give the food matrix binding and viscosity, as well as kibble expansion. Although dogs do not require carbohydrates, they are a significant source of e.nergy and help to keep kibbles together (Corsato Alvarenga, Aldrich and Shi, 2021). Cornappears to be a rare source of allergies in dogs' meals (Olivry and Bexley, 2018).
Legumes	Legumes are well utilized by dogs. However, they usually need to beheated to deactivate anti-nutritional agents and increase digestion ofthe dogs (Corsato Alvarenga, Aldrich and Shi, 2021).
Gluten	A combination of pea protein isolate and wheat gluten can be used to create fibrous meat mimics with matrix strength similar to cookedchicken flesh (Schreuders et al., 2019)
Dried eggs	The egg proteins exhibited the greatest protein efficiency ratio (PER) values and would not require any amino acid or supplementary protein supplementation to reach a state of total dietary adequacy.
Gelatin	Gelatin is a flavourless, odourless, and tasteless powder that isformed from collagen. In dry extruded pet food, low-bloom gelatin might function as a nutritious binder (Manbeck et al., 2017).
Plasma and animal by products	Due to technological qualities such as gel strength, water retention, and fat emulsion capabilities, spray-dried animal plasma (SDAP) is utilized in canned pet food (Polo et al., 2009). Bioactive peptides in animal feed can be found in animal by-products. In such, antimicrobials, antioxidants, opioid-like and/or other intriguing bioactive compounds found in protein hydrolysates from animal by-products have prospective and fascinating applications on companion and production animals (Martínez-Alvarez, Chamorro and Brenes, 2015).
Gums (Xanathan. Cassia, Guar)	Xanthan gum is approved for use as a food ingredient in a variety ofgoods with varying levels of moisture. At the specified conditions ofusage, the results of effectiveness experiments in numerous feeding stuffs revealed that xanthan is an effective stabiliser and thickener infeeding stuffs. At the suggested circumstances of application, xanthan gum is regarded an effective stabiliser and thickener in feedstuffs for all animal species (Bampidis et al., 2021).
Sodium and potassium alginate	Alginates work well as thickeners, stabilisers, gelling agents, and binders. Potassium alginate is indicated for use in cat and dog food at concentrations of up to 40,000 mg/kg feed on dry matter (Rychen et al., 2017).
Plant by products (coconut oil)	Itchy skin, scrapes, wounds, and ear difficulties are among the other complaints. Dogs treated topically for bites, stings, ear mites, ear infections, scrapes, or wounds often cease scratching immediately after coconut oil is given to their diet, and dogs treated topically for flea allergies, contact dermatitis, or other allergic responses typically recover rapidly (Puotinen, 2005).

2.10.2 Stabilier

Natural antioxidants (curcumin, cranberry, pomegranate, and grape seed extract (GSE) might be utilised to replace synthetic antioxidant butyl-hydroxytoluene (BHA) which acts as stabliser in dog food. According to the findings (Glodde, Günal, Mary E Kinsel, et al., 2018), Curcumin dose (100 mg per kg of diet) was determined using data from other animal species as there because is no yet standard as references of curcumin in canine diets (Campigotto et al., 2020).

2.10.3 Gelling Agents

In animal food preservations, gelling agents increase the processing uniformity while also controlling moisture. Examples of gelling agents are bean and guar gums, cellulose, carrageenan, and other starches and thickeners. Yeast, protein, fat, fish solubles, sweeteners, and concentrated tastes known as digests can all improve palatability. Artificial tastes are rarely utilized, though some sweets may include smoke or bacon flavors. Due to some vitamins and minerals may be lost during processing, most pet food producers add vitamins and minerals to their products (Ockerman and Hansen, 1988).

2.11 Types of Dog Food Product

More than 3,000 different pet food options are available, including dry, canned, and semi-moist varieties, as well as snacks like biscuits, kibbles, and treats (Ockerman and Hansen, 1988).

2.11.1 Dry Food

Dry pet food as in Figure 5 compared to canned food contains no more than 10% of moisture. Dry food utilized ingredients such as corn gluten feed, meat and bone meal, animal fats, and oils are some of the other ingredients. Dry food is mostly prefer by pet owners due to ease and cost as if compared to imported dog food (Dilruskshi H.N.N., 2009). Dry meals require more amylaceous, or starch, components of proteinaceous adhesives, such as collagen, albumens, and casein; and plasticizing agents to get a meat-like texture (Ockerman and Hansen, 1988). A study has conducted by (Goi, Simoni, et al., 2020) to determine the total and gelatinized starch, insoluble fibrous fractions, and mineral content in extruded dry dog food predicted using a hand-held near-infrared spectrometer. The best statistics were achieved by external validation for gelatinized starch, with an RPD of 2.55 and 2.03 in ground and intact samples, respectively. In other study (Goi, Manuelian, et al., 2020) conduct a study to see if visible/near-infrared reflectance (Vis-NIR) and near-infrared transmittance (NIT) spectroscopy could accurately predict total and gelatinized starch, as well as fibre fractions, in extruded dry dog food. Dry dog food has shelf life of 10 to 12 months and requires preservatives. Some producers use natural preservatives such vitamins E and C (Ockerman and Hansen, 1988). Dry pet foods, extruded or baked account for over 70% of the market, are majority prepared by extrusion cooking and required a concentrated protein source to meet nutritional requirements and product claims (Donadelli et al., 2019). As a result, pet food manufacture moved to dry meals made from oven-baked dry food broken into smaller, irregular bits (Sanderson, 2021). The low moisture content of dry food helps to inhibit the growth of most organisms.

Figure 5: Dry dog food (Burkhardt, 2019).

2.11.2 Wet Food (Canned)

The most common type of wet pet food is canned food. The level of moisture in canned and dry pet foods is the main distinction. The moisture content of canned food ranges from 70% to 80%. Vacuum-packed canned dog foods have a shelf life of three to five years and are stable, with little or no nutritional value loss (Ockerman and Hansen, 1988).

2.11.3 Semi-moist

Binders, which can include gels, cereal flours, sulfur-containing amino acids, lower alkyl mercaptans, lower alkyl sulphides and disulfides, salts, and thiamin, are commonly used in semi-moist pet feeds. Soybean flakes, bran flakes, soluble carbohydrates, emulsifiers, stabilisers, and dry skim milk and dried whey are all possible additions to semimoist goods. Antioxidants are frequently utilised to prevent fat oxidation and rancidity. Butylated hydroxy anisole (BHA), butylated hydroxy toluene (BHT), and tocopherol are among them. Producers utilize sucrose, propylene glycol, sorbic acid, or potassium and calcium sorbates to suppress mould and bacterial growth. Dry and semi-moist foods can be extruded under high pressure through a device with orificed plates to achieve desired shape and size, such as biscuits, kibbles, meatballs, patties, pellets, or slices (Ockerman and Hansen, 1988).

2.11.4 Snacks (Kibbles, Treats, Biscuits)

Majority of marketable snacks are baked and necessary to have functioning proteins that can aid in binding (Dilruskshi H.N.N., 2009). Baking technique is used for producing treats, and extrusion technique for making kibbles. Extrusion technique is same to the process of making breakfast cereals (Ockerman and Hansen, 1988). Extrusion is now used to make the majority of dry dog kibbles. However, on the present pet food market, biscuit treats appear to be holding constant (Anton Beynen, 2020a).

2.12 Common Pet (Dog) Food ingredients

Table 6: Base flour mix composition (Burkhardt, 2019).

Ingredients	**Percentage (%)**
Chicken meal	30.4
Pea flour	19.4
Pea potato	16.4
Potato, whole dried egg	17.9
Beet pulp	8.9
Flaxseed	6.0
Fish oil	0.6
Vitamin mix	0.2
Trace minerals	0.1

Based flour mix composition of dog food can be referred in Table 6 above. Animal-based proteins, on average, exhibited more complete amino acid profile than plant-based proteins, which was reflected in improved consumer performance (Donadelli et al., 2019).

Table 7: Ingredients and nutritional composition of dog food using extrusion technology (Campigotto et al., 2020).

Ingredients	**Contents**
Corn	373.25
Bone and meat meal 45%	210.00
Defattened rice brand	200.00
Bean bands	140.00
Oil of boiler offal	40.00
Hydrolysed broiler liver	30.00
Mineral premix	2.00
Vitamin premix	2.00
NaCI	1.00
Antioxidant	0.50
Antifungi	1.00
Yucca schidighera extract	0.25
Crude protein (g/kg)	181.7
Ether extract (g/kg)	102.8
Crude fibre (g/kg)	50.0
Calcium (g/kg)	24.0
Available phosphorus (g/kg)	13.3
Sodium (g/kg)	2.00

Table 7 above displays the ingredients and nutritional composition of dog food using extrusion technology. The computed dose of daily ingested curcumin was 6 mg/dog and 1.5 mg/kg BW based on the amount of feed taken by each dog per day and BW, as well as the concentration of genuine curcumin. By lowering lipoperoxidation and raising antioxidant levels, curcumin added to the diet of dogs enhanced feed quality and extended feed preservation. Curcumin enhanced canine health by promoting erythropoiesis and the antioxidant system, as well as perhaps stimulating protective effects on the liver; however, additional research is needed to confirm this finding (Campigotto et al., 2020).

2.13 Chicken Bone-based Dog Food Manufacturing

Figure 6 below shows the results of binder, tapioca, egg and gelatin. According to (Burkhardt, 2019), 1.2% of wheat straw lignin binder required in a dry basis. As for tapioca, egg and gelatin 5% required. The manufacturing processes including mix, die cut and bake.

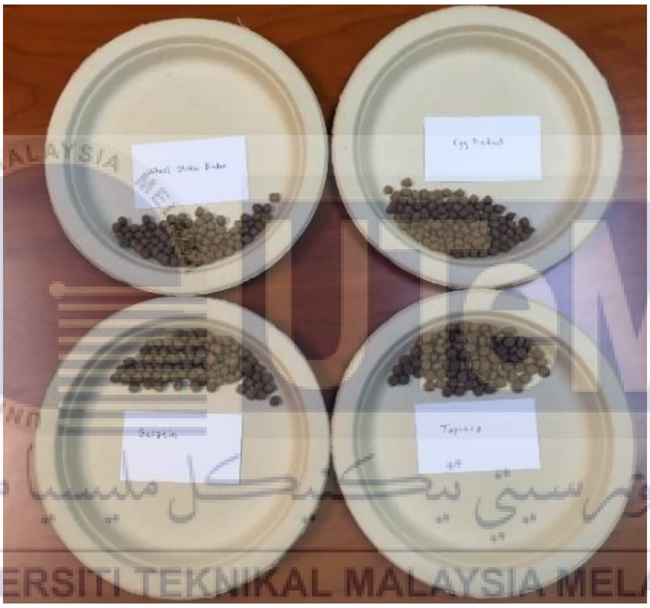


Figure 6: Results of binder, tapioca, egg and gelatin (Burkhardt, 2019).

2.13.1 Chicken Bone Wastes

Increased consumption of chicken meat results in an increase in chicken bone waste. Chicken bone waste as in Figure 7 below is frequently discarded since it has little commercial uses (Dwandaru and Sari, 2020). Humans are unable to consume some foods, such as chicken bones and egg shells. Hence, it is unavoidable food waste in Chicken bone waste (CBW) is a plentiful organic waste as chicken meat consumption has increased by 27.13 %, and the presentation menu of chicken meat has become more instant without bone (Nursyafarinah et al., 2019). Chicken bones are a waste product of the chicken meat industry and restaurants. Collagenous and non-collagenous protein, for example, are important organic substances found in chicken bones (Kumoro et al., 2010). Chicken bones consist of inorganic and organic materials, as well as water. The main inorganic material is calcium phosphate or known as hydroxyapatite. Chicken bones are a source of protein such as collagen (Dwandaru and Sari, 2020). Chicken bone is one the wastes that is seldom or never employed in the production of animal feeds, pet food, or fertilizers (Cansu and Boran, 2015).

Figure 7: Chicken bone waste.

2.13.2 Chicken Bone Waste-based Dog Food Manufacturing

The manufacturing of chicken bone waste into powder can be seen in Figure 8 below. Firstly, the chicken bones were gathered from local chicken flesh filleting shops' garbage, washed, dried in the sun, cooked in a 250°C oven for 2 hours, and crushed into powder (Dwandaru and Sari, 2020). Food waste was collected from domestic waste (Mahssin et al., 2021). Secondly, the remaining meat from chicken bones are cleaned before drying under sun for 2 hours. During the treatment, (Cansu and Boran, 2015) revealed that a significant portion of contaminants were carefully eliminated, and over 80% of the original collagen was maintained. Then, chicken bones are heated in electrical oven at 250°C for 2 hours. After that, chicken bones are grinded to become powder. Next, the powder is filtered through sieve to ensure its size is homogenous.

Figure 8: Chicken bone manufacturing processes (Dwandaru and Sari, 2020).

2.13.3 Dog Food Manufacturing Process

Baked-food makers promote baking as a delicate procedure with time-honored which preserve the nutrients and tastes of the ingredients. Oven-baked foods are those that have been cooked in the oven. The baking temperature is left unmentioned. Baked dog food is prepared in the following manner. Biscuits are formed, cooked at 200 degrees Celsius, cooled, and packed after the ingredients and water are combined. When the ingredient combination is extruded, it passes through the extruder momentarily at around 130°C and high pressure, and then air-pops when it enters the ambient air. Baked food, in contrast to extruded kibbles, contains less air and has a higher density. Baked-food manufacturers claim that their goods allow dog owners to feed their pets less. They also claim of having a better taste and digestion. There is no proof for the three allegations in the public domain. In fact, they can only be assessed by feeding, preference, and digesting experiments with dogs fed the same component mixture but baked or extruded in different ways. Baked food is also said to lessen the incidence of bloated stomach to the dog. However, this claim is unproven. The dough is pushed into a die that has the shape and depth that is needed. The formed kibbles are baked in a tunnel oven at 200 degrees Celsius for 10 minutes, or until they have attained a moisture content of 10% (Anton Beynen, 2020b). The moisture content of the dog food can be obtained by weighing the sample before and after drying as in equation 1. The experiment needs to be conducted in triplicate (Tumuluru, Conner and Hoover, 2016).

$$\text{Moisture content } (\% \text{ w.b}) = \frac{weight\ of\ sample\ after\ drying\ (g)}{weight\ of\ sample\ (g)} \times 100 \qquad \text{Equation 1}$$

2.13.4 Existing Dog Food Products in the Market (Chicken-based)

Table 8: Existing chicken-based dog food products in the market.

Manufacturer/Product	**Guaranteed analysis**	**Ingredients**
Nestle Thailand Ltd, Thailand 	Compliant with AAFCO andHACCP	Corn, wheat, soya rice, dehydrated chicken and meat, chicken oil, hydrolysed chicken and meat, vitamins and minerals, choline, calcium, phosporous, chloride, copper, iodine, manganese, selenium, invert syrup, dehydrated fish protein
International Pet Food Co., Ltd, Thailand 	Per 100g; Protein – 24 % Fat – 9 % Moisture – 20 %	Chicken meat, water, glycerine, sucrose, flavors, preservatives, antioxidant, colorings,
International Pet Food Co., Ltd, Thailand 	Per 100g; Protein (min) – 24 % Fat (min) – 9 % Fibre (max) – 1 % Moisture (max) – 20 %	Chicken meat, wheat flour, glycerine, water, sugar, tapioca starch, wheat gluten, powdered cellulose, soy lecithin, salt, sodium tripolyphosphate, tocopherol, sodium erythorbate, colouring, beta-carotene

International Pet Food Co., Ltd, Thailand 	Per 100g; Protein (min) – 24 % Fat (min) – 9 %	Chicken meat, tapioca, vegetable glycerine, sugar, natural chicken meat flavour, skim milk, salt, sodium tripolyphosphate, vitamin E
NUTRIX Public Co. Ltd, Thailand 	Compliant with AAFCO	Tapioca flour, soy bean meal, wheat bran, corn, poultry meal, tallow, rice, corn gluten meal, poultry fat, digested animal protein, salt, vitamins supplement, trace minerals supplement, Dicalcium Phosphate, Edible Fiber, rice bran oil, salmon oil, preservative agent (propionic acid), green tea powder, choline chloride.
Perfect Companion Group CO., Ltd., Thailand 	Compliant with AAFCO andHACCP	Rice, poultry meal, corn gluten meal, soybean meal, chicken oil, beet pulp, flax seed, dried whole egg, brewer's dried yeast, lecithin, fish oil, milk replacer, iodized salt, vitamins and minerals, food coloring and antioxidants

Based on Table 8 above, most of existing dry dog foods in the market are made up of starches, chicken meat, vitamins, minerals and oil. All of dog food are compliant with AAFCO in which the ingredients are included in the packaging. As to avoid stomach upsets, allow 7 to 10 days to ease transition from dog's current food to the new meal. Gradually add more and less of the previous food to the dog's bowl until changeover is complete.

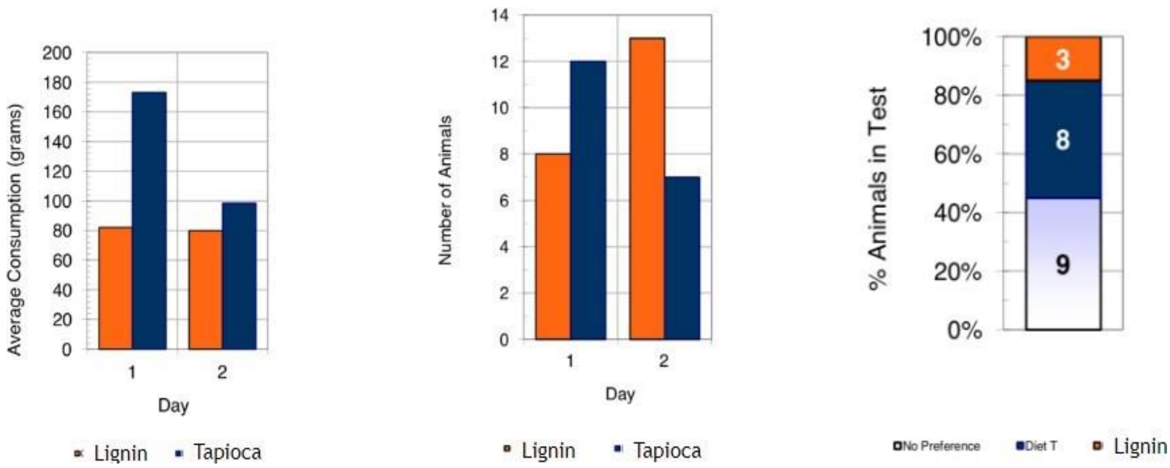


Figure 9: Lignin vs tapioca (Burkhardt, 2019).

2.14 Dog Food Testing (Lab Analysis)

Table 9: Nutrient profile of unbleached wheat straw coproduct (Burkhardt, 2019).

Component (%)	**As DM**
Crude protein	5.0
Crude fat	2.3
Est. Carbs	44.9
Ash	47.8
Total Digestible Nutrients	46
K	1.92
Na	11.87
Ca	0.11
P	0.06
Mg	0.05

Based on Table 9 above regarding nutrition lab analysis of nutrient profile for the unbalanced wheat straw coproduct. Est Carbs includes other organic material such as lignin. As for other nutrients detected at ppm level (Fe, Zn, Cu, Mn). However, heavy metals not detected.

(Burkhardt, 2019) revealed that in 85% of dogs chose lignin-based binder or had no preference. Meanwhile, 75% less binder is required to obtain the same amount of binding as gelatin, egg, or tapioca when used as a drop-in substitute for gelatin. Complete salt is the replacement in kibble diet. Gluten and grain-free replacement for current binders as shown in Figure 9 above. According to the researchers, consumption and first choice preference will be recorded. Based on the results obtained by authors, 85% of dogs preferred or had no preference for lignin-based binder vs egg. Hence, drop-in replacement for gelatin. 75% less of binder needed to achieve same level of binding as gelatin, egg or tapioca. Complete replacement of sodium in kibble diet. Gluten and grain-free alternative to existing binders. Reduction in use of binders allows for less fillers.

CHAPTER 3

METHODOLOGY

This chapter introduces the methodology used in this research. The objective of this research is to produce stray dog food from recycle chicken bone waste. This chapter covers the overall methodology of the research, selection of controlled process parameters, methodology of process sequence in manufacturing of the dog food, preparation of raw material, sample fabrication preparation, and feeding trial products to the stray dog. The process flow shall be based on the process flow and the Gantt chart. In order to meet the defined targets, the research will follow the guidelines and ensure that the attempts made to achieve these objectives are not diverted from the objectives.

3.1 Overview

The preparation of methodology is to make sure the preparation of raw material from food waste and product sample fabrication are as planned and expected. The procedures set up are according to scopes of the research to achieve the objectives set up. The methodology uses in this research is as flowchart shown in Figure 10. The research has been separated into five main stages as follows:

Stage 1: Preparation of raw material
Stage 2: Preparation of sample fabrication
Stage 3: Produce sample
Stage 4: Dog feeding experimental strategy
Stage 5: Postulate the results

3.2 Research Methodology Flowchart

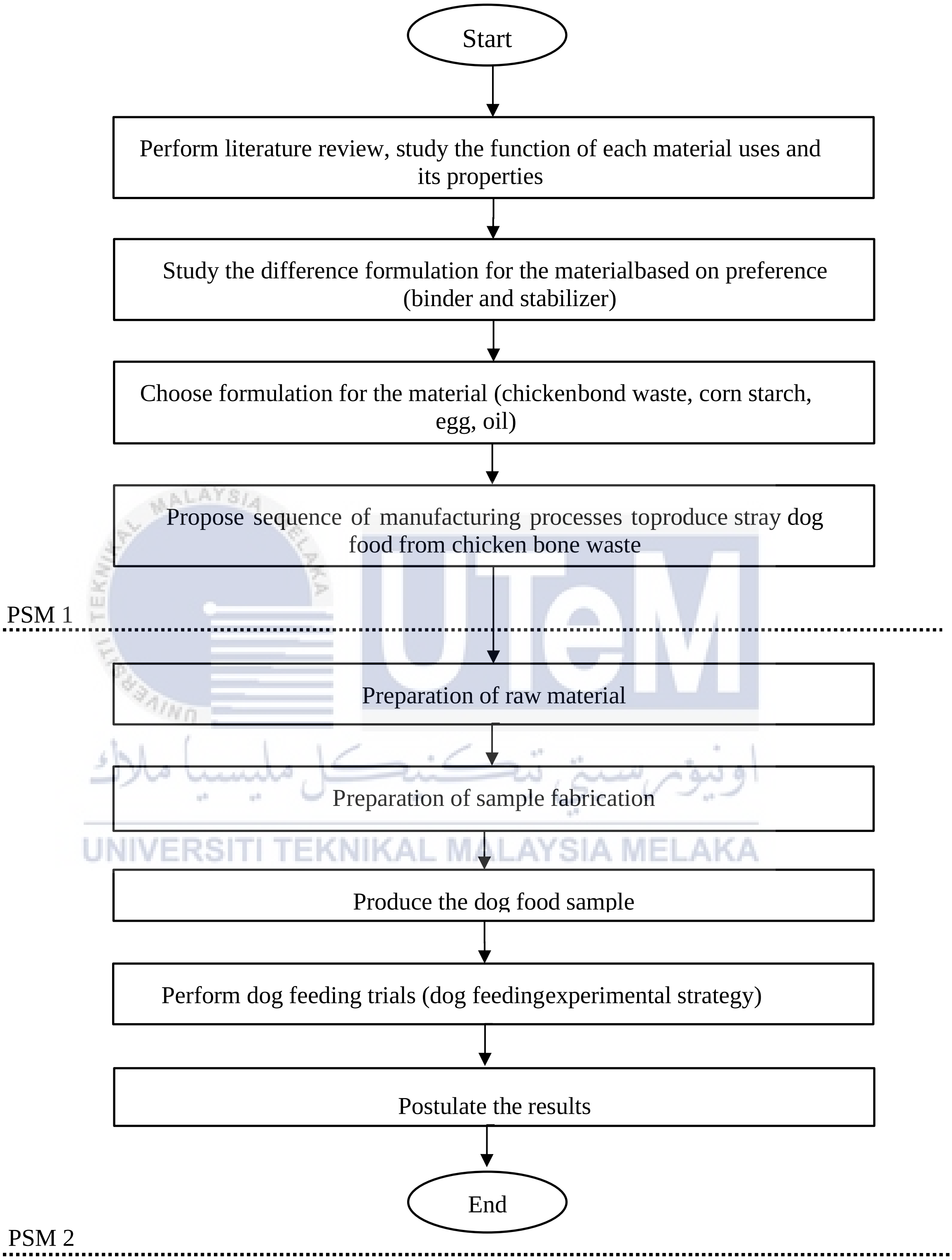


Figure 10: Research flowchart methodology.

3.3 Controlled Process Parameters

Table 10: Research process parameters.

No.	Parameters	Description
1	Drying temperature	60°C
2	Drying duration	24 hours
3	Ingredients	Raw material (chicken bone)
		Binder (Corn starch, whole egg and coconut oil)
		Stabiliser (curcumin powder)
4	Preheat temperature (fix)	130°C to 210°C
5	Preheat duration (may vary)	20 to 80 mins

Based on Table 10 above, the temperature during drying will be fixed at 60°C while for baking temperature is 130°C to 210°C. Drying will performed using Memmert drying oven as to ensure crushing of the chicken can be done successfully. As for drying temperature, it will be fixed to 60°C but baking duration is from 20 to 80 minutes respectively. However, the ingredients used include chicken bone waste, corn starch, whole egg, coconut oil and curcumin powder are fixed. These parameters are considered based on the previous study related to dog food manufacturing.

3.4 Materials

The materials used in the remanufacturing of chicken bone waste into dog food are including chicken bone waste as raw materials, corn starch, whole eggs and coconut oil as binder and curcumin as stabiliser.

3.4.1 Raw Material

Chicken bone waste as in Figure 11 is the raw material used to produce the stray dog food. In this study, cooked chicken bone wastes are utilized as the raw material. The chicken bone wastes are crushed using crusher machine into powder which then mixed with additional additives of binders and stabilizer. It is important to ensure the chicken bone is processed evenly and properly to ensure good quality of dog food can be produced as to avoid eating problems to the dog as the chicken bone waste is the main material in the production of the dog food. The chicken bone waste can easily be collected from many sources collected from many sources such as household. There will be no problems in the chicken bone waste sustainability as raw material in this research. The chemical composition of chicken bone waste is shown in Table 11 below.

Figure 11: Collected chicken bone wastes.

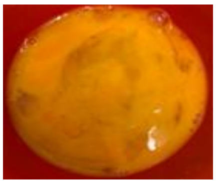
Table 11: Chemical composition of Chicken Bone.

Composition	**Percentage (%)**
Nitrogen	2.9
Protein	15.6
Fat	9.5
Mineral	14.7

3.4.2 Binders

Table 12 below displays the binders used in this research. All binders are bought from supermarket nearby Ayer Keroh, Malacca. The binders are part of ingredients of the dog food production. The binders are used to bind all ingredients together so that product will not break when being packed. However, moisture of the product needs to be optimized. Although the binders including corn starch, tapioca flour, dried egg and coconut are fixed, however, the amount and quantity in the dog food is vary depending on the other ingredients amount. Therefore, four sample will be produced as to obtain the best result of the food with different adjustment of the controlled process parameters.

Table 12: Composition of Binders.

Binder	Composition	Value (Unit)	Description
 Corn starch.	Amylose Amylopectin Crude fats Crude proteins Ash Phosphor Moisture content Density	24.64 g/100g 75.36 g/100g 7.13 g/100g 7.70 g/100g 0.62 g/100g 0.09 % 10.45 % 1.4029 g/cm^3	Dogs can digest and metabolise starches effectively. It gives food matrix binding to keep ingredientstogether. It rarely causes allergen to dogs
 Whole dried eggs.	Carbohydrate Moisture (max) Fat (min) Protein (min) Ash	0.6% 5.0 % 40.0 % 45.0 % 3.7 %	It has storage life of 5 to 10 yearsaccording to the environment. There is no chance of contamination from breakage ofshells
 Coconut oil	Free fatty acid (max) Moisture (max) Iodine value (cg 12/g) Density (g/ml) colour	0.2 % 0.1 % 4.1 - 11 0.915 -0.920 colourless	It's one of the few saturated-fatvegetable oils on the planet.

3.4.3 Stabiliser

Stabilizer also an important element in the dog food production as to maintain the dog food shelf life. Curcumin is natural antioxidants, can be used to substitute BHA. The curcumin was bought from any supermarket nearby Ayer Keroh, Malacca. The curcumin powder is utilized to preserve the dog from spoilage. It is widely used in food industries. The amount of curcumin required in the study is depending on amount of other ingredients.

Figure 12: Curcumin powder as stabilizer.

3.5 Manufacturing Process Sequence

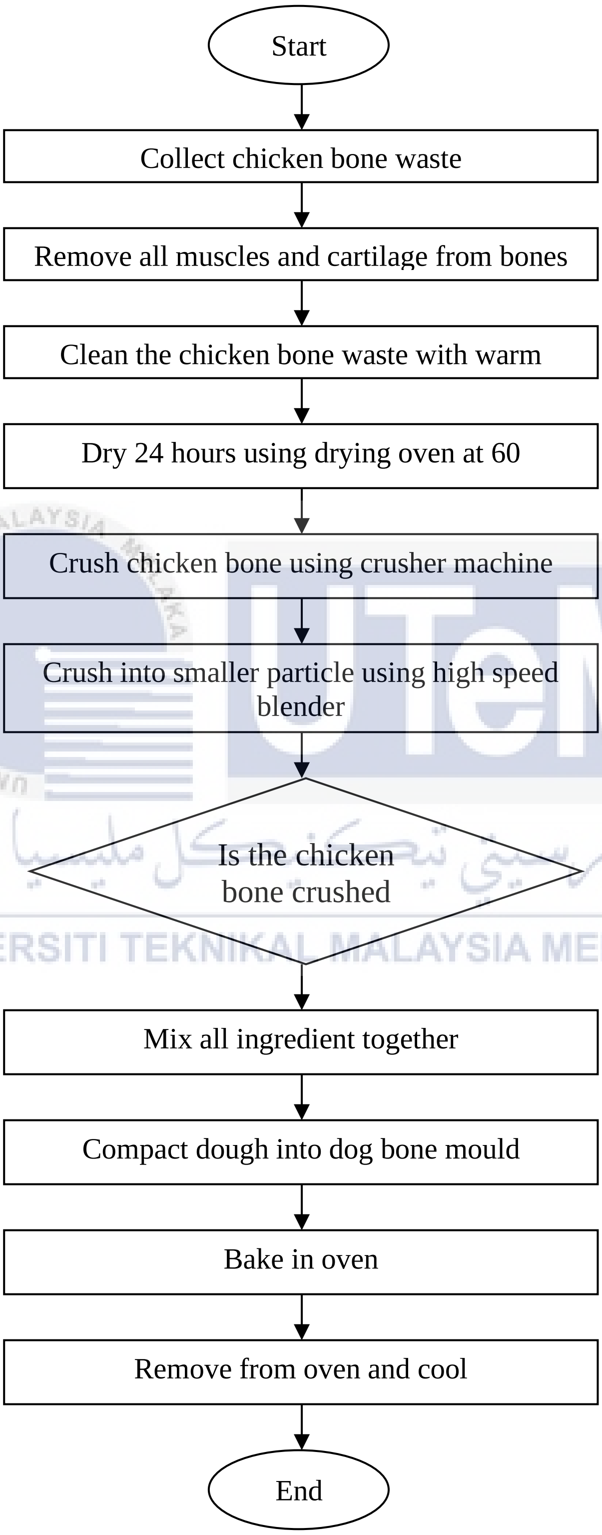


Figure 13: Research manufacturing process flowchart.

3.6 Raw Preparation Process

The preparation of the raw material can be referred in Figure 17. The first step in raw material preparation is chicken bone waste collection. Second step is removing all muscles and cartilage chicken bones. Third step is cleaning the chicken waste using warm water. Afterwards, proceed with sample fabrication preparation.

3.7 Sample Preparation Process Fabrication Preparation Process

Sample fabrication processes including oven drying chicken bones using drying oven for 24 hours, crash chicken bones using crasher machine, crush chicken bone into smaller particles using high speed blender, mix all ingredients such as binder and stabilizer into the crushed chicken bones, compact the dough into dog-boned mould, bake dough in oven, and finally remove from oven and let cool in room temperature.

3.7.1 Weigh the Chicken Bone (Electronic Scale)

Weighing the chicken bone in oven is the first step in sample fabrication. Electronic scale as in Figure 12 will be used in this process. The chicken bones need to be weighed to know measure moisture of the chicken bone. The moisture of the chicken bone can be calculated by dividing after slow bake and before slow bake then time by 100%. Moisture is the important element in dog food.

Figure 14: Electronic scale.

3.7.2 Drying Process (Drying Oven)

Drying the chicken bones in oven is the second step in sample fabrication. This process is performed using Memmert drying oven as in Figure 13. The machine can be obtained in laboratory of Faculty of manufacturing, UTeM. This process is important to ensure easy crashing of the chicken bones into powder. During drying, temperature is fixed at 60°C to ensure crushing of the chicken bones can be performed successfully.

Figure 15: Memmert dry oven.

3.7.3 Crushing process (Crasher Machine and High-Speed Blender)

Third step is crashing chicken bones using crasher machine as display in Figure 14. The machine also can be obtained in laboratory of Faculty of manufacturing, UTeM. During this process, the piece of chicken needs to closely monitor to ensure crushing of the chicken can be done successfully. Then, the chicken will be crushed into smaller particle using high speed blender as in Figure below.

a) b)

Figure 16: a) Crusher machine b) High Speed Blender

3.7.4 Mixing Process

Once the chicken bones are easily crushed into powder, binder (corn starch, whole egg and coconut oil) and stabilizer (curcumin) will be added to the powder. Amount of binder and stabilizer is depending on amount of the chicken bone powder. The mixture needed to be evenly mixed. The mixing process needed to be repeated until even dough can be obtained.

3.7.5 Compacting Process (Dog-boned Mould)

Next step in sample fabrication is compacting the dough into a dog-boned mould to ensure the ingredients of food sample attach firmly to each other. The equipment as in Figure 15 is chosen from others as it is expected to compact the dough well by pressing the dough in mould using the provided mould stick. The mould is bought via Shoppe online shopping. The mould is used to produce dog food which is ergonomic to the dog's mouth. The mould is the suitable for making snacks for the dog as part of scopes in the research.

Figure 17: Dog-boned mould.

3.7.6 Baking Process (Electric Oven)

Baking is the final step in sample fabrication. This process required the dough to be baked in the electric oven as in Figure 12. This process is performed to ensure the dough is dried evenly and ingredients are attached firmly. This is to ensure the dog food will not be broken when being packed. However, the moisture of the dog food must be ensured as well. The important parameters for this process are preheat temperature preheat duration. The baking temperature will be fixed to from 130° to 210°C and baking duration vary from 20 to 80 minutes respectively during this process. If the sample is baked well, the sample will be taken out from oven and cooled at room temperature. Then, sample is ready to be trial tested to the stray dogs.

Figure 18: Electric oven.

3.8 Feeding Trial or Feeding Test

Table 13: Feeding Trial Parameters.

Testing Parameters	Description
Number of dogs require	3 (stray dogs)
Duration of trials	3 days
Feeding amount per day	30g
Observation techniques	a) weigh the food before and after meal
	b) examine the dogs' condition within experimentduration

Feeding trial parameters are shown in Table 13 above. During the observation, the condition of the dogs will be examined. As to keep the data, the experimental observation will be monitored and analyzed to see if the food fit the stray dogs' diet or either way. If nothing happened to the dog during trial feeding in term of eating problem, the product is then safe to be fed to the stray dogs. The report of the feeding trial needs to be kept as per AAFCO' reference if the product may cause some problems to the consumers (stray dogs) in the future.

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 Introduction

This section will discuss the ingredients composition used for this research. This chapter consists of the critical review obtained from the existing journals and postulated results which estimated from the analysis conducted on the review data from at least three relevant journals. In this chapter also, the results and discussion are divided into several subtopics which are: (1) comparison of ingredients composition for dog food production (2) chronology of manufacturing process results (3) effect of baking temperature and time to the samples (4) moisture content (%) analysis (5) optimal process parameters (6) feeding trial analysis. This chapter is mainly explained the data collected after completed the sample fabrication and testing experiment. All the hypothesis and discussions will be stated and supported using the previous research statement for this research.

4.2 Comparison of Ingredients Composition for Dog Food Production

This section will discuss comparison of ingredients composition used in this research with previous studies. In a study conducted by (Dilruskshi H.N.N., 2009), local ingredients including corn, rice flour, rice polish, animal fat, soy bean meal, chicken fish meal, hypro meal, eggs, vitamin premixes, and baking soda are used for making dog food. Similarly, the ingredients used to produce the dog food in this research also all local ingredients. From Table 14 below can be seen the list of ingredients used for dog's food making in this research including chicken bone, corn flour, whole egg, coconut oil and curcumin powder. The difference is the content of ingredients used. Previous study used rice flour, rice polish, animal fat, soybean meal, hypro meal, vitamin premixes, and baking soda while not being used in this study. Coconut oil and curcumin powder as being used for this research also not being used in study by (Dilruskshi H.N.N., 2009). The similarity is both studies used chicken meal. However, ingredients used in this research is lesser compared to previous study. Researcher (Surie, 2014) mentioned that majority of pet owners are looking for treats that are organic and include few ingredients. As mentioned earlier, this research focused in making food for stray dog meanwhile previous study focused to domestic or breed dogs. However, most formulation are similar to ingredient composition for dog food in (Virk et al., 2019) research.

Table 14: Ingredient composition (%) of dog biscuits in control diet (Virk et al., 2019).

Ingredient	**Percentage (%)**
Refined wheat flour (maida)	55
Vegetable oil	20
Whole egg liquied	16
Spice mix	3
Sugar	3
Table salt	2
Baking powder	1

As for binder including corn starch, whole egg, and coconut oil used for this research are commonly used in dog food production. Binders in dog food are used to bind all the ingredients together from breakage. Gluten presence in the corn starch establishes protein matrix which helps to harden biscuit treats texture (Jan, Saxena and Singh, 2016). Other study by (Pietrasik and Soladoye, 2021) found that the presence of a starch of any type increased product firmness and enhanced moisture retention. Starch a very promising as binder for wet granulation(Vandevivere et al., 2019).

Table 15:Postulated ingredients composition for this research.

Ingredients Composition	**Sample**					
	1	**2**	**3**	**4**	**5**	**6**
Curcumin powder (%)	3	3	3	3	3	3
Chicken Bone (%)	20	25	30	35	40	45
Coconut oil (%)	20	20	20	20	20	20
Corn starch (%)	47	42	37	32	27	22
Whole egg (%)	10	10	10	10	10	10

As for stabiliser, curcumin powder is chosen to be used as stabilizer as to maintain and protect the dog food from spoilage up to 12 months. Stabilizer in the dog food helps to protect the food from spoilage. Previous study proof that curcumin and its derivatives are efficient at reducing the rate of lipid oxidation (Glodde, Günal, Mary E. Kinsel, et al., 2018). In their study, the researchers suggested to add curcumin to dog food as it is safe and works effectively to lower lipid oxidation. Curcumin added to the diet of dogs improved feed quality and prolonged the preservation of the feed by reducing lipoperoxidation and increasing levels of antioxidants (Campigotto et al., 2020).

As for binder including corn starch, whole egg, and coconut oil used for this research are commonly used in dog food production. Binders in dog food are used to bind all the ingredients together from breakage. Gluten presence in the corn starch establishes protein matrix which helps to harden biscuit treats texture (Jan, Saxena and Singh, 2016)**.** Other study by (Pietrasik and Soladoye, 2021) found that the presence of a starch of any type increased product firmness and enhanced moisture retention. Starch a very promising as binder for wet granulation(Vandevivere et al., 2019).

From (Almeida, Koppel and Aldrich, 2022) research finding, from soluble animal protein dog treats were successfully produced using rotary moulding, they discover that soluble animal protein have similar physical and binding characteristics to dog treats made with wheat. Similar finding also found by (Almeida, Koppel and Aldrich, 2022) in their study where wheat that contain gluten which are widely used in pet treats production can give better dough structure, durability, and texture to pet treats. However, they also concluded that due to wheat that contain gluten is primarily composed of protein kafirin prolamin which has issues with texture and breakage when used in pet treat production.

4.3 Chronology of Manufacturing Process Results

From a study by (Dilruskshi H.N.N., 2009), the chronology manufacturing process used in their research can be seen from Figure 19 below. The chronology process separated into sub process which were mixing all ingredient (maize, rice flour, rice polish, hypo meal, soya bean meal and fish meal together and blending the eggs and minced chicken flesh. Afterward, water and animal fat were added to the mix which then resulted in paste form. Next process was pelleting the paste into desired shape as well to enhance the paste from separation. Finally, oven drying was required to produce firm pellets at 105°C for 24 hours.

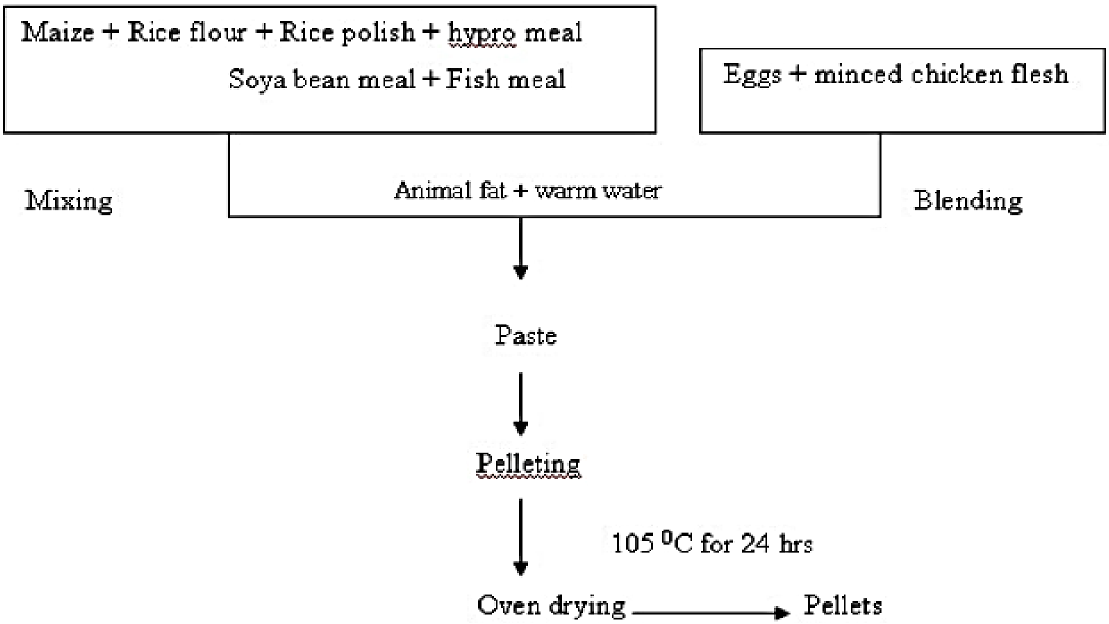


Figure 19: Dog food preparation (Dilruskshi H.N.N., 2009).

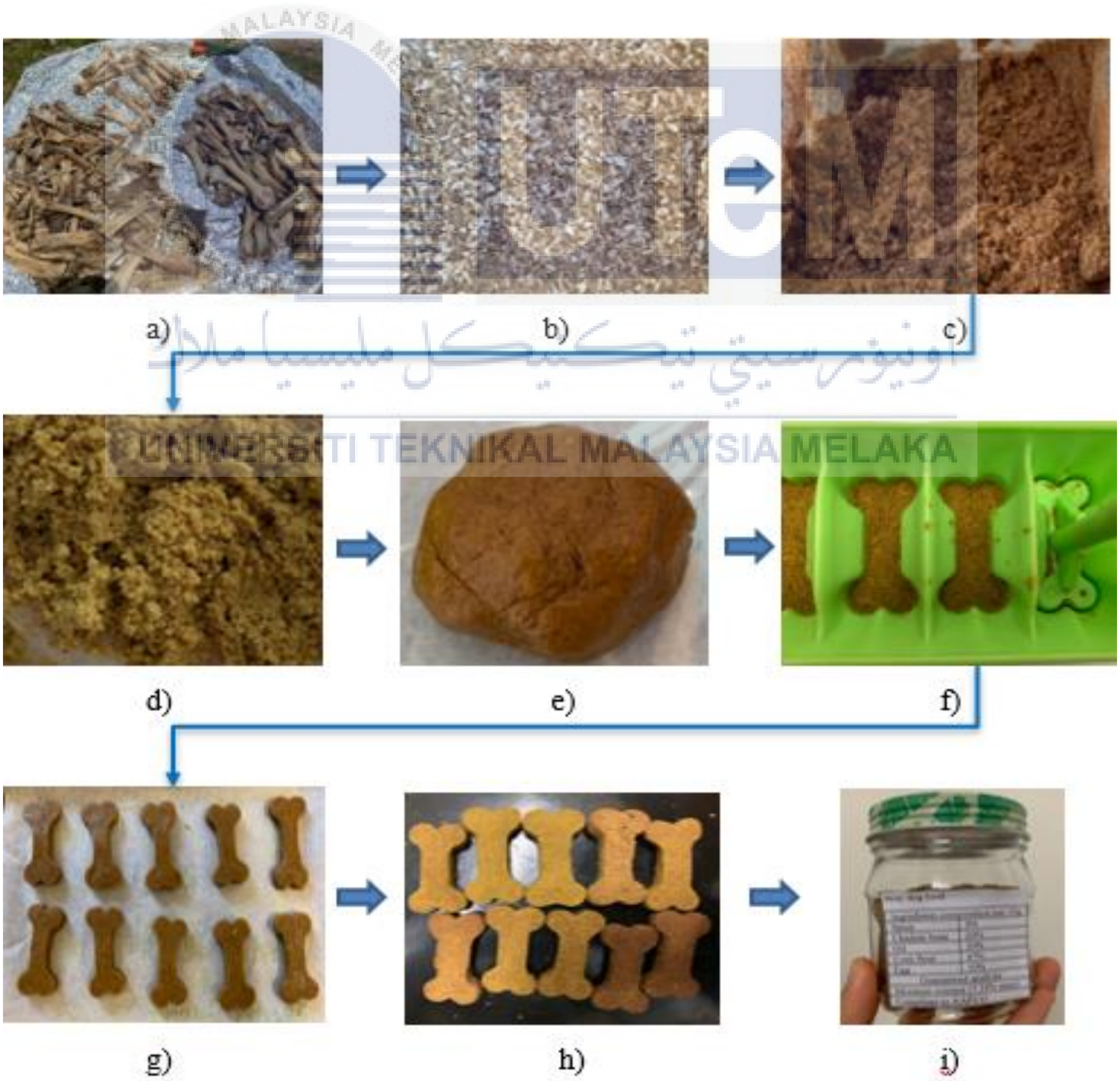


Figure 20: Research chronology of manufacturing process results.

Figure 20 above shows the chronology of the manufacturing results where a) chicken bone being collected and cleaned b) crushed using crusher machine c) crushed using high speed blender d) ingredients being mixed e) dough result f) compacted dough to the mould g) dough being compacted to mould results h) baked biscuit treats for dog and i) packed biscuit treats for stray dog. As the dog food was made based on chicken bone waste, more attention must be paid in the manufacturing processes to produce good quality product.

The chronology of the manufacturing process starts with chicken bones being collected and cleaned from plate waste followed by crushing chicken bone until get into powder like using crusher machine and high- speed blender. When crushed using crusher machine, the particle size of chicken bine is around 3mm which is not safe to dog. This is because the particles are sharp and hard. If they were used to produce the dog food, injuries to dog's mouth and stomach may occur. For this reason, the chicken bones needed to be crushed into smaller particle high speed blender.

The chicken bones when crushed using high speed blender resulted in powder-like particle and determine safe when use in dog food production. Suppose that the chicken bones can directly be crushed using high-speed blender, but it cannot be done due to hardness of the bones. The process after crushing was mixing all ingredients together. The amount of each ingredients used were weighted using electronic scale in percentage. As to ensure ingredients were precisely weighted, three readings were made for each weighting activity. Mixing resulted into dough results. Six doughs were produced as six samples were required.

Afterwards, the dough was compacted dough to the mould before being baked. Finally, the biscuit treats were packed to avoid oxidation. Appropriate package is very important in dry pet food products to control moisture adsorption and avoid oxidation which can cause off-flavors and odors to the food during long-term storage produce (Manzocco et al., 2020). List on ingredients were attached to the package as to fulfilling the AAFCO requirement.

From the chronology of the manufacturing process results, can be concluded that dog food manufacturing in this research was replicated to human's baked biscuits. In such, manufacturing process of making biscuit from (Chanioti, 2019) research where mixing, molding, baking and cooling are important factors for controlling the consistent quality of the produced product.

4.4 Effect of Baking Temperature and Time to Samples

Six samples were produced based on the ingredient composition. Each sample has 8 pieces of biscuit treat in which initially each piece weighted 10g each. The samples were baked according to batches at different temperature from 160°C to 210° and time from 80 minutes to 60 minutes respectively. First batch was baked at 130° for 80 minutes, second batch was baked at 160°C for 60 minutes, third batch was baked at 190°C for 40 minutes, and forth batch baked at 210°C for 20 minutes. The results of baking temperature and time on products are as presented in following Table 1, Table 2, Table 3, Table 4, Table 5 and Table 6.

Table 16: Sample 1 result.

Batches	**Weigh (g)**		**Temperature (°C)**	**Time (minutes)**	**Moisture content (%)**	**Remark**
	Before	**After**				
1 (a)	10	7.25	130	80	8.33	Baked evenly
1 (b)	10	7.19			6.33	Baked evenly
2 (a)	10	8.23	160	60	41.00	Baked evenly
2 (b)	10	8.35			45.00	Baked evenly
3 (a)	10	8.52	190	40	50.67	Slightly burnt
3 (b)	10	8.47			49.00	Slightly burnt
4 (a)	10	8.14	220	20	38.00	Slightly burnt
4(b)	10	7.56	220	20	18.67	Slightly burnt

Sample 1 was produced using 3% curcumin powder, 20% chicken bone, 20% coconut oil, 47% corn starch and 10% whole egg. The result obtained from sample 1 as in Table 15 above shows that samples baked evenly at 130 C° for 80 minutes and at 160°C for 60 minutes. When baked at 190°C and 220°C for 40 and 20 minutes respectively, the samples were slightly burnt. For sample 1, sample batch 1(b) has the lowest moisture content of 6.33% while sample batch 3(a) has the highest moisture content of 50.67%. In average, when baked at 130°C for 80 minutes, it resulted in lowest moisture content while when baked at 190°C for 40 minutes resulted in highest moisture content for ingredient composition of 3% curcumin powder, 20% chicken bone, 20% coconut oil, 47% corn starch and 10% whole egg. Hence, this clearly shows that sample batch 1(b) with moisture content of 6.33% is the best batch for sample 1.

Table 17: Sample 2 results.

Batches	Weigh (g)		Tempraturee (°C)	Time (minutes)	Moisture content (%)	Remark
	Before	After				
1 (a)	10	7.18	130	80	6.00	Baked evenly
1 (b)	10	7.27			9.00	Baked evenly
2 (a)	10	7.21	160	60	7.00	Baked evenly
2 (b)	10	7.29			9.67	Baked evenly
3 (a)	10	8.19	190	40	39.67	Slightly burnt
3 (b)	10	7.92			30.67	Slightly burnt
4 (a)	10	8.26	220	20	42.00	Slightly burnt
4 (b)	10	8.21			40.33	Slightly burnt

Sample 2 was produced using 3% curcumin powder, 25% chicken bone, 20% coconut oil, 42% corn starch and 10% whole egg. The result obtained from sample 2 as in Table 16 above shows that samples baked evenly at 130 C° for 80 minutes and at 160°C for 60 minutes. When baked at 190°C and 220°C for 40 and 20 minutes respectively, the samples were slightly burnt. For sample 2, sample batch 1(a) has the lowest moisture content of 6% while sample batch 4(a) has the highest moisture content of 42%. In average, when baked at 130°C for 80 minutes, it resulted in lowest moisture content while when baked at 220°C for 20 minutes resulted in highest moisture content for ingredient composition of 3% curcumin powder, 25% chicken bone, 20% coconut oil, 42% corn starch and 10% whole egg. Hence, this clearly shows that sample batch 1(a) with moisture content 6% is the best batch for sample 2.

Table 18: Sample 3 results.

Batches	Weigh (g)		Temperature (°C)	Time (minutes)	Moisture content (%)	Remark
	Before	After				
1 (a)	10	8.16	130	80	38.67	Baked evenly
1 (b)	10	8.04			34.57	Baked evenly
2 (a)	10	8.07	160	60	35.67	Baked evenly
2 (b)	10	7.51			17.00	Baked evenly
3 (a)	10	8.25	190	40	41.67	Slightly burnt
3 (b)	10	8.19			39.67	Slightly burnt
4 (a)	10	8.09	220	20	36.33	Slightly burnt
4 (b)	10	8.2			40.00	Slightly burnt

Sample 3 was produced using 3% curcumin powder, 30% chicken bone, 20% coconut oil, 37% corn starch and 10% whole egg. The result obtained from sample 3 as in Table 17 above shows that samples baked evenly at 130 C° for 80 minutes and at 160°C for 60 minutes. When baked at 190°C and 220°C for 40 and 20 minutes respectively, the samples were slightly burnt. For sample 3, sample batch 2(b) has the lowest moisture content of 17% while sample batch 3(a) has the highest moisture content of 41.67%. In average, when baked at 160°C for 60 minutes, it resulted in lowest moisture content while when baked at 220°C for 20 minutes resulted in highest moisture content for ingredient composition of 3% curcumin powder, 30% chicken bone, 20% coconut oil, 37% corn starch and 10% whole egg. Hence, this clearly shows that sample batch 2(b) with moisture content 17% is the best batch for sample 3.

Table 19: Sample 4 results.

Batches	Weigh (g)		Temperature (°C)	Time (minutes)	Moisture content (%)	Remark
	Before	After				
1 (a)	10	8.19	130	80	39.67	Baked evenly
1 (b)	10	8.25			41.67	Baked evenly
2 (a)	10	8.16	160	60	38.67	Baked evenly
2 (b)	10	7.92			30.67	Baked evenly
3 (a)	10	8.33	190	40	44.33	Slightly burnt
3 (b)	10	7.87			29.00	Slightly burnt
4 (a)	10	8.72	220	20	57.33	Slightly burnt
4 (b)	10	8.25			41.67	Slightly burnt

Sample 4 was produced using 3% curcumin powder, 35% chicken bone, 20% coconut oil, 32% corn starch and 10% whole egg. The result obtained from sample 4 as in Table 18 above shows that samples baked evenly at 130°C for 80 minutes and at 160°C for 60 minutes. When baked at 190°C and 220°C for 40 and 20 minutes respectively, the samples were slightly burnt. For sample 4, sample batch 3(b) has the lowest moisture content of 29% while sample batch 4(a) has the highest moisture content of 57.33%. In average, when baked at 160°C for 60 minutes, it resulted in lowest moisture content while when baked at 220°C for 20 minutes resulted in highest moisture content for ingredient composition of 3% curcumin powder, 35% chicken bone, 20% coconut oil, 32% corn starch and 10% whole egg. Hence, this clearly shows that sample batch 3(b) with moisture content 29% is the best batch for sample 4.

Table 20: Sample 5 results.

Batches	Weigh (g)		Temperature (°C)	Time (minutes)	Moisture content (%)	Remark
	Before	After				
1 (a)	10	8.17	130	80	39.00	Baked evenly
1 (b)	10	8.11			37.00	Baked evenly
2 (a)	10	7.83	160	60	27.67	Baked evenly
2 (b)	10	7.66			22.00	Baked evenly
3 (a)	10	8.22	190	40	40.67	Slightly burnt
3 (b)	10	8.33			44.33	Slightly burnt
4 (a)	10	8.29	220	20	43.00	Slightly burnt
4 (b)	10	8.26			42.00	Slightly burnt

Sample 5 was produced using 3% curcumin powder, 40% chicken bone, 20% coconut oil, 27% corn starch and 10% whole egg. The result obtained from sample 5 as in Table 19 above shows that samples baked evenly at 130 C° for 80 minutes and at 160°C for 60 minutes. When baked at 190°C and 220°C for 40 and 20 minutes respectively, the samples were slightly burnt. For sample 5, sample batch 2(b) has the lowest moisture content of 22% while sample batch 3(b) has the highest moisture content of 44.33%. In average, when baked at 160°C for 60 minutes, it resulted in lowest moisture content while when baked at 190°C for 40 minutes and 220°C for 20 minutes resulted in highest moisture content for ingredient composition of 3% curcumin powder, 40% chicken bone, 20% coconut oil, 27% corn starch and 10% whole egg. Hence, this shows that sample batch 2(b) with moisture content 22% is the best batch for sample 5.

Table 21: Sample 6 results.

Batches	**Weigh (g)**		**Temperature (°C)**	**Time (minutes)**	**Moisture content (%)**	**Remark**
	Before	After				
1 (a)	10	8.03	130	80	34.33	Baked evenly
1 (b)	10	7.76			25.33	Baked evenly
2 (a)	10	8.15	160	60	38.33	Baked evenly
2 (b)	10	8.22			40.67	Baked evenly
3 (a)	10	8.16	190	40	38.67	Slightly burnt
3 (b)	10	8.21			40.33	Slightly burnt
4 (a)	10	8.33	220	20	44.33	Slightly burnt
4 (b)	10	8.28			42.67	Slightly burnt

Sample 6 was produced using 3% curcumin powder, 45% chicken bone, 20% coconut oil, 23% corn starch and 10% whole egg. The result obtained from sample 6 as in Table 20 above shows that samples baked evenly at 130 C° for 80 minutes and at 160°C for 60 minutes. When baked at 190°C and 220°C for 40 and 20 minutes respectively, the samples were slightly burnt. For sample 6, sample batch 1(b) has the lowest moisture content of 25.33% while sample batch 4(a) has the highest moisture content of 44.33%. In average, when baked at 130°C for 80 minutes, it resulted in lowest moisture content while baked at 190°C for 40 minutes and 220°C for 20 minutes resulted in highest moisture content for ingredient composition of 3% curcumin powder, 45% chicken bone, 20% coconut oil, 22% corn starch and 10% whole egg. Hence, this shows that sample batch 1(b) with moisture content of 25.33% is the best batch for sample 6.

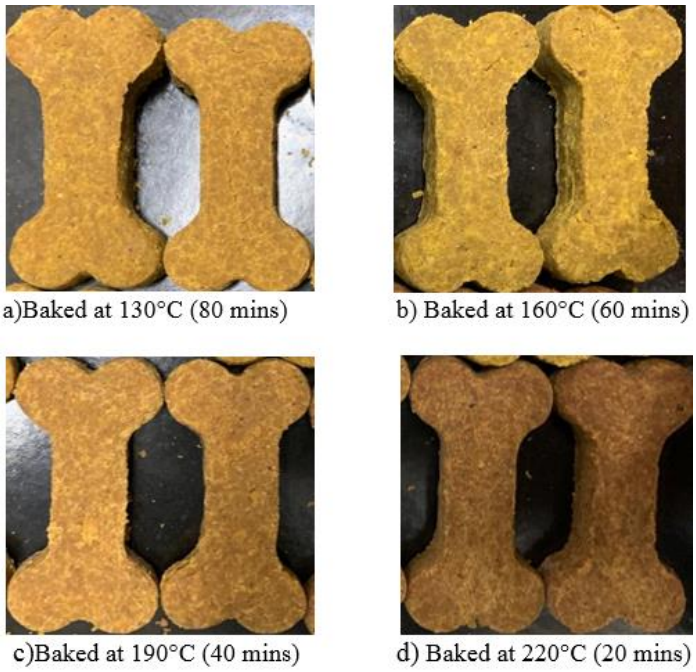


Figure 21: Dog food samples baked at different temperature and duration.

From Figure 27 above can be seen there were differences between samples being baked at different temperature and time. When baked at 130°C for 80 minutes and 160°C for 60 minutes, the samples are evenly baked. In contrast, when baked at 190°C for minutes and 220°C for 20 minutes, the samples were slightly burnt. When baked 160°C, the samples seemed to result more yellowish if compared to others. Samples resulted to be darker when baked at 220°C. More yellowish to darker means about to be cooked and started being slightly burn. This indicates that when samples become darker, they are slightly burnt. Hence, can be concluded from Figure 27 in terms of well-cooked is when samples were baked at 130°C for 80 minutes. Thus, colour of the food also plays important role in dog food production.

4.5 Moisture Content (%) Analysis

Moisture content is a very important element in dog food production. Most studies revealed that moisture of dry dog food is below 10%. A study by (Kritikos et al., 2018) stated that foods having moisture content of less than 10% were classified as dry. Recent studies revealed that moisture content is an important element in dry food as the low moisture content of dry food helps to inhibit the growth of most organisms (Sanderson, 2021). This is because dry dog foods in the market have a longer shelf life when having less moisture. Therefore, the samples that having moisture content below that 10% is classified as dry. For all samples having moisture content below than 10%, they are evaluated as to estimate the most optimum parameters among the samples in terms of baking temperature and duration.

From (Başer and Yalçin, 2017) research, the moisture of dog dry foods was found to be ($P<0.01$) within range of 4.44% to 8.22%. In other study, (Barbosa-Cánovas et al., 2008) also observed that pet dry foods contained 4.4% moisture. In experimental diets conducted by (Di Donfrancesco, Koppel and Aldrich, 2018), they agreeed that dry basis shoould has moisture below 10%.

Research by (Alegría-Morán et al., 2019) found that dry foods having high moisture is said to have lower dry matter is good to enhance food palatability and dogs preference to the food. However, finding in research by (Almeida, Koppel and Aldrich, 2022) found that treat moisture between 3-8% did not vary across treatments with average values fluctuating. For this reason, before creating product, some authors advise examining the fat composition and level of oxidation that ingredients have because an ingredient with a very high oxidation level can cause a rise in the amount of primary oxidation products, and after processing secondary oxidation products may accumulate (Manzocco et al., 2020). (Başer and Yalçin, 2017) in their concluded that the use of different raw materials in foods and the extrusion process could be to blame for the difference in moisture content.

For this reason, the moisture content for the dog food produced in this research must below 10% and only then the dog food can be classified as dry. The moisture content below 10% must be achieved as it is one scope for this project. The result of moisture content for each sample for biscuit treats can be seen from Figure 22, Figure 23, Figure 24 and Figure 25 followings. Hence, the comparison of moisture content between sample will be discussed and evaluated based on literature reviews of previous studies. In general, any samples that having result below 10% is said to achieve the moisture content requirement for dry dog food.

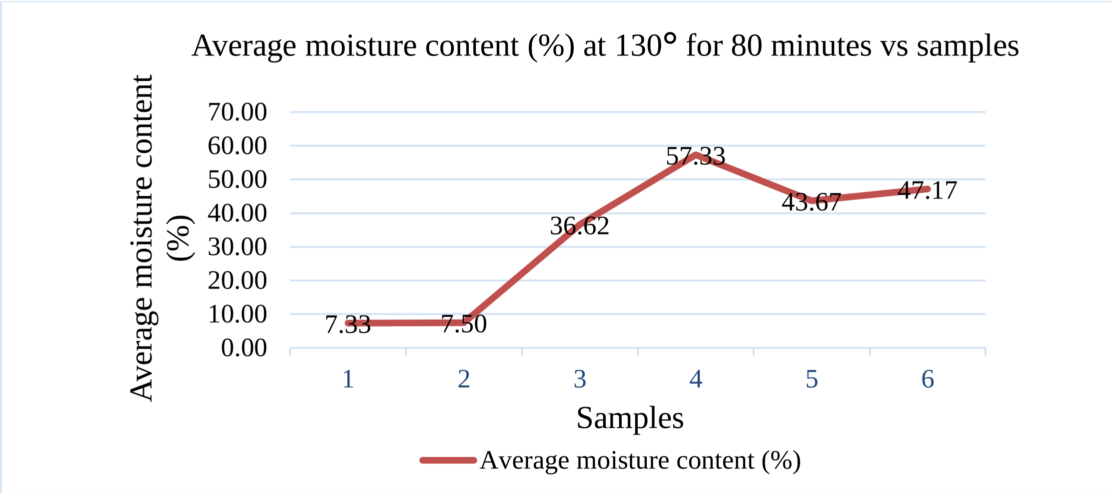


Figure 22: Average moisture content (%) at 130° for 80 minutes vs samples.

From graph Figure 22 above, when baked for 80 minutes at 130°C, sample 1 and 2 having moisture content 7.33% and 7.50% respectively. This indicates that sample 1 and 2 achieved the requirement of dry basis moisture content which is below than below 10% which is comparable to study conducted by (Bramoulle, 2013). Therefore, sample 1 and 2 baked at these parameters could be optimal parameters in producing dog food for this research. However, other consideration also needs to take into account especially the ingredients composition to produce the stray dog food as in Table 14 earlier as for this research. As samples 3,4,5, and 6 moisture content are above 10%, hence, indirectly, they are not the optimal parameter when baked at these parameters as they did not fulfill the important requirement for dry dog food basis matter.

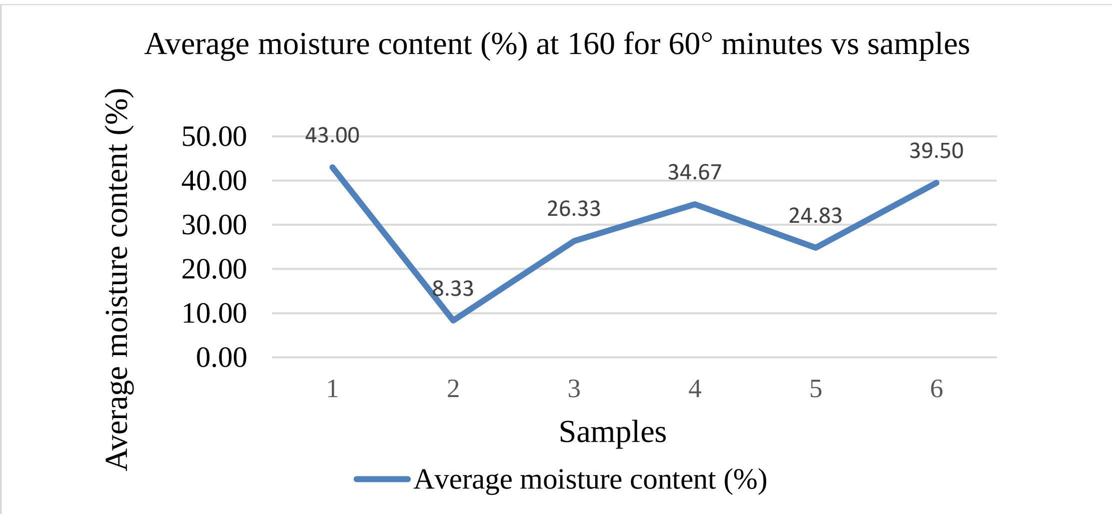


Figure 23: Average moisture content (%) at 160° for 60 minutes vs samples.

From graph Figure 23 above, when baked for 80 minutes at 160°C, sample 2 has moisture content 8.33% .This indicates that sample 2 achieved the requirement of dry basis moisture content which is below than below 10% which is comparable to study conducted by (Bramoulle, 2013). Therefore, sample 2 baked at these parameters could be optimal parameters in producing dog food for this research. However, other consideration also needs to take into account especially the ingredients composition to produce the stray dog food as in Table 14 earlier as for this research. As samples 1,3,4,5, and 6 moisture content are above 10%, hence, indirectly, they are not the optimal parameter when baked at these parameters as they did not fulfill the important requirement for dry dog food basis.

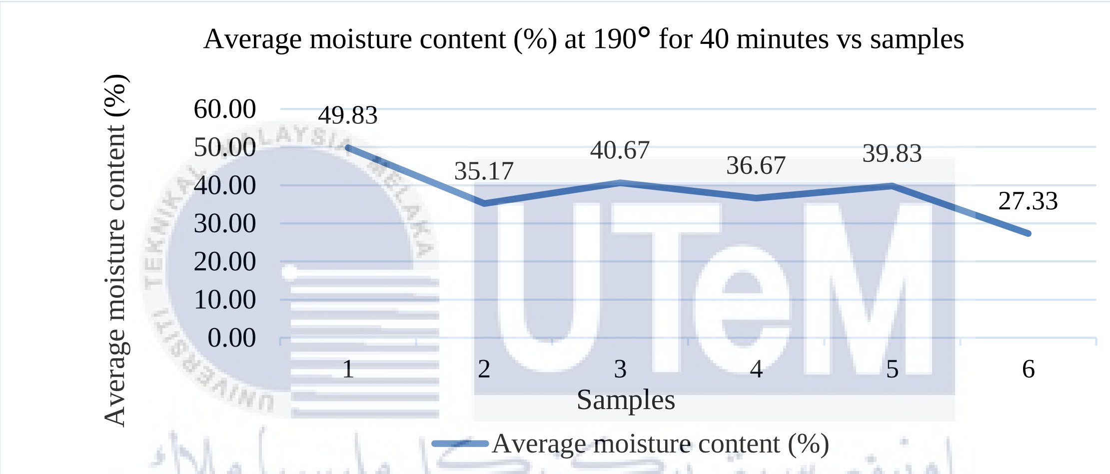


Figure 24: Average moisture content (%) at 190° for 40 minutes vs samples.

From graph Figure 24 above, when baked for 40 minutes at 190°C, all samples result in moisture above 10%. Indirectly, all samples are not the optimal parameter when baked at these parameters as they did not fulfill the requirement for dry dog food basis.

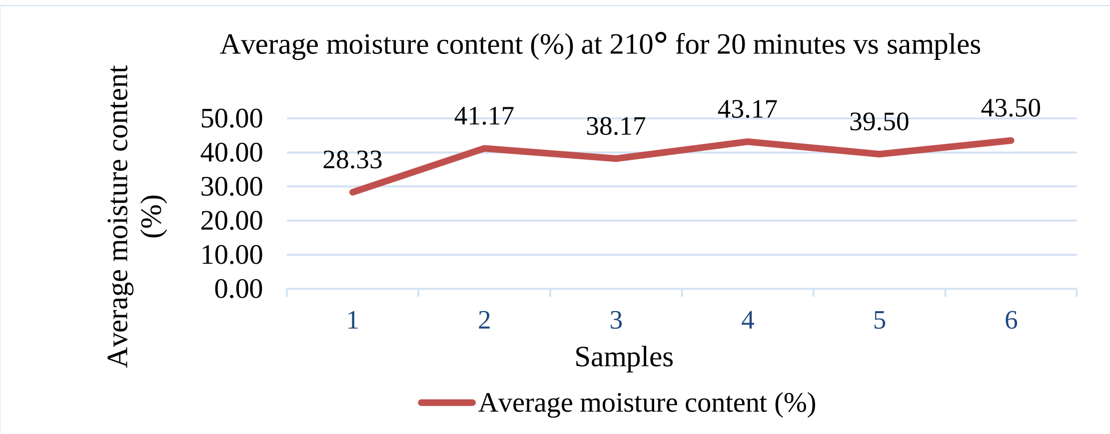


Figure 25: Average moisture content (%) at 220° for 20 minutes vs samples.

From graph in Figure 25 above, when baked for 20 minutes at 210°C, all samples result in moisture above 10%. Indirectly, all samples are not the optimal parameter when baked at these parameters as they did not fulfill the requirement for dry dog food basis.

The moisture content Overall, sample 1 baked at 130°C for 80 minutes, sample 2 baked at 130°C for 80 minutes, and sample 2 baked at 160°C for 60 minutes achieved the requirement of moisture content (%) in dry dog food as they achieved moisture content below 10% which consistent to result in most studies. Therefore, among these three samples, the optimal parameters can then be identified by considering their ingredients composition in Table 14 earlier.

4.6 Optimal Process Parameters

For this study, the optimal parameters will be identified based on samples moisture content and ingredient composition. From the moisture content analysis earlier, only three samples achieved the requirement of moisture content for dry basis. The three sample were sample 1 baked at 130°C for 80 minutes, sample 2 baked at 130°C for 80 minutes, and sample 2 baked at 160°C for 60 minutes. Initially, sample 1 baked at 130°C for 80 minutes was produced from 3% curcumin powder, 20% chicken bone, 20% coconut oil, 47% corn starch and 10% whole egg. As for sample 2 baked at 130°C for 80 minutes, and sample 2 baked at 160°C for 60 minutes, both were produced using 3% curcumin powder, 25% chicken bone, 20% coconut oil, 42% corn starch and 10% whole egg. Sample 1 at 130 ℃ for 80 minutes is the best parameters to produce the dog food.

As to summarize, all samples were produce using same percentage of curcumin powder, coconut oil and whole egg. The difference in thier ingredient compositions were percentage of chicken bone and corn flour. From Table 14 earlier, sample 1 utilized 20% chicken bone and 47% coconut oil while sample 2 utilized 25% chicken bone and 42% corn flour. Therefore, it is better to choose sample 2 as it utilized higher percentage of chicken bone if compared to sample 1. This helps to reduce the chicken bone waste from being dumped to the landfill which contribute to open food waste. It is better to utilized chicken bone for stray dog food.

As batches of sample 2 having same percentage of ingredient composition, hence, baking parameters could be considered as to determine the optimal parameters to bake the stray dog food in this research. A research by (Chanioti, 2019) stated that dog biscuit better be baked at 130℃ but baking time was more than 15. Therefore, sample 2 baked at 130℃ for 80 minutes has the optimal parameters to baked the stray dog food in this research which relevant to result obtained in (Chanioti, 2019) research. Sample processed within longer time had the highest hardness, samples in shorter time had the lowest hardness (Tu, 2021).

Interestingly, baking temperatures may help to inactive enzymes which responsible for oxidation and favor auto-oxidation (Maire et al., 2013). Although Maillard Reactions Products (MRP) produced from baking temperatures can be antioxidants (Barden and Decker, 2013) but, iron has not affect towards oxidation stability of treats due to low moisture in the product (Almeida, Koppel and Aldrich, 2022). Not to forget, density is also important index for the sensory texture of biscuit treats in such greater crispiness and better texture is a result from lower density. In dry dog food, there is a high amount of moisture loss results to lesser density in the food (Manohar and Rao, 2002). This is one reason why biscuit treats are popular among pet's owners thus hold stable market in pet food market.

4.7 Feeding Trial Analysis

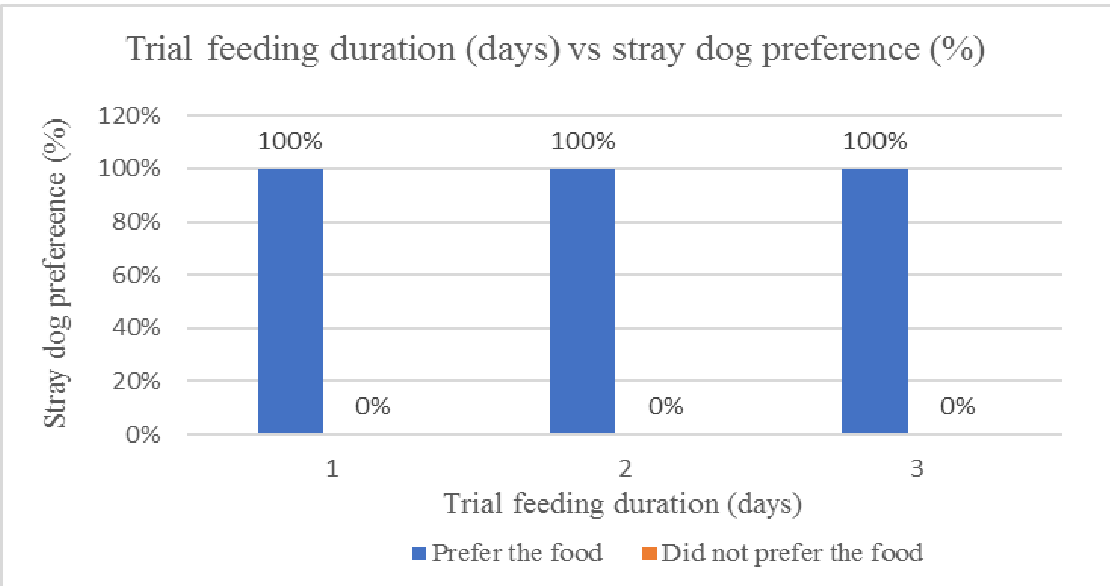


Figure 26: Feeding trial result.

Feeding trial in this research conducted to observed the stray dogs' preferences to the produced food. (Virk et al., 2019) also conducted test to test dog acceptability to the biscuits in their research. According (Almeida, Koppel and Aldrich, 2022), it is very important to assess the acceptance by dogs. Trial feeding is conducted to understand the stary dogs' preferences as they are incapable to provide verbal feedback. The dogs' preferences can be determined according to amount of food eaten by them (Tobie, Péron and Larose, 2015). From feeding trial result in Figure 26 above, all of stray dogs during the preferred the food produced in this research. None of the dogs faced problems during the trial feedings. The result from research feeding trial is consistent to result obtained by (Anton Beynen, 2020a) where baked-food have better taste and digestion, also lessen the incidence of bloated stomach. However, baked food should be fed less to the dogs (Anton Beynen, 2020a).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

Overall, the objectives for this research have been successfully achieved. The first objective of this research is to propose the sequence of manufacturing processes to produce stray dog food from chicken bone waste. The data collected are analyzed and significant conclusions for this objective are as follows;

i. The proposed sequence of manufacturing processes has been successfully utilized to produce stray dog food sample from chicken bone waste.

ii. Different composition of ingredients will give different result on temperature and duration to produce the stray dog food.

The second objective of this research is to produce stray dog food sample from chicken bone waste using controlled parameters based on animal food manufacturing standard adopted from regulation of American Association of Feed Control Officials (AAFCOO). Ingredients composition and process parameters are the main factors to produce the dog food sample. Feeding trial also important element as to ensure the food samples are successfully produced. The significant conclusions for this objective are as follows;

i. Best parameters to remanufacture the stray dog food from recycle food waste are at 130° for 80 minutes using composition of 20% chicken bone waste, 47% corn flour, 20% coconut oil, 10% whole egg, 3% curcumin powder.
ii. The produced food samples passed feeding trials experiment to the stray dogs.

iii. Therefore, chicken bone waste has proven can be remanufactured into stray dog food with reference to AAFCO standard.

5.2 Recommendations

After gone through this research, there are few recommendations suggested so be able to call attention to the important aspect need to be focus on for coming research topic about application of food waste into dog food applications. The significant recommendations for this objective are as follows;

i. As the scope for this research is only for strays, future study also should be conducted to produce food for breed or domestic dogs using similar parameters in this research. However, many factors should be considered including dogs' owners to get involve with the research.

ii. More study should also be conducted to produce food for stray dogs as there are very limited studies and research focusing to the needs of the stray dogs.

iii. Studies to convert other type of food waste beside chicken bone waste into dog food also should be taken into account as food waste are unavoidable in our daily life.

iv. Moreover, other study at other stages should be conducted to study other factors for the product including dog owners' preferences for dog foods such factors of pet age, activity level, breed and health, besides, cost analysis should be studied as it is an important event in new product development.

v. Future studies need to be aimed at finding a suitable effective dose of the supplements for enhancing health of stray dog food.

vi. Further studies must be done with pet foods subclassified to age, wet and semi-moist pet foods by utilizing chicken bone waste.

vii. Further study should be done to compare acceptance of stray dog for food remanufactured from chicken bone waste for wet basis and canned food.

5.3 Sustainability Element

In general, sustainability element consists of four pillars including human, social, environment and economic. Sustainability element is very important in live as to ensure we live a better life. Even nowadays, most manufacturers are turning their ways to more a sustainable way as people have huge interest in products that concern with sustainability. Same to this research, the idea is to produce sustainable stray dog food using minimum ingredients and least manufacturing processes. Most importantly, this research utilized recycle food waste as the raw material.

Upon successful of this research, the amount of chicken bone waste can be reduced of being disposed to the landfills. Chicken bone waste is almost 25% from 17 tonnes of food wastes produces each day. I believe this product in long term could catch attention of many dogs' owners. Per assumption, the cost for this product is the cheapest in the market as the materials and machines to produce the dog food are cost effective. Electricity used to produce the dog food also can be minimized as the dog food can be produced in one run massively.

In addition, curcumin powder has higher availability and lower cost in comparison to the other antioxidants used in dog food production which relevant to study conducted by (Glodde, Günal, Mary E. Kinsel, *et al.*, 2018). Chicken bone is very sustainable as the amount of chicken bone disposed are increasing each day. Besides, very little manufacturers utilized chicken bone in production. Undeniable, chicken is the main menu consumes in each household and restaurants except for vegetarian.

Through this research, I did not realize any company that utilized chicken bone in their production. To some degree, the data and results obtained may contribute to the society in many ways, especially in the engineering and manufacturing field. For this reason, the research to recycle food waste into new value-added products always needed improvement from time to time for the purpose of moving forward to the future. Last but not least, the manufacturing of stray dog food in this research without doubt has included sustainable element.

5.4 Life-Long Learning Element

This research indirectly able to widen our knowledge and open our mind about the relationship between engineering and real-life problems. Throughout this research, the critical thinking skill to determine and find solutions to remanufactured chicken bone waste into stray dog food is very important. Few alternatives should be taken until the solution suits the problems. Thus, self-confident along with scientific knowledges also required in solving problems related to engineering and others. From this research, it is very important to have solid understanding on selecting ingredients used to produce the dog food. The used of chicken bone as raw material in the stray dog food production can minimized food waste at the landfills. As to conclude, food waste such as chicken bone waste can be remanufactured into new value-added product.

5.5 Complexity Element

The complexity element in this research is in term of finding the suitable ingredients to produce the stray dog food as to use minimum ingredients possible. This is because there are many dogs' food already existed in the market. Besides, conducting the feeding trial to the stray dog also very challenging. It is also challenging to find the most suitable parameters for this research as each sample need to well- prepared to maintain quality of the dog food. Not to forget that the preparation of the chicken bone waste is challenging. Much time was spent to collect the chicken bone. After being collected, chicken bone needs to directly process to avoid from spoilage. After oven dried, the chicken bone needs to directly crush then keep in seal container to avoid exposure to moisture which could spoil the chicken bone.

REFERENCES

Ajila, C.M. et al. (2012) 'Bio-processing of agro-byproducts to animal feed', Critical Reviews in Biotechnology, 32(4), pp. 382–400. doi:10.3109/07388551.2012.659172.

Alegría-Morán, R.A. et al. (2019) 'Food preferences in dogs: Effect of dietary composition and intrinsic variables on diet selection', Animals, 9(5), pp. 1–12. doi:10.3390/ani9050219.

Alexander, P. et al. (2020) 'The global environmental paw print of pet food', Global Environmental Change, 65. doi:10.1016/j.gloenvcha.2020.102153.

Almeida, K.A.L., Koppel, K. and Aldrich, C.G. (2022) '201 Shellenberger Hall, 1301 Mid Campus Drive North', p. 66506. doi:10.1093/jas/skac191/6590789.

Anton Beynen (2020a) 'Baked dog food', Petfood, pp. 1–7. Available at: https://www.researchgate.net/publication/340271675_Beynen_AC_2020_Baked_dog_food

Anton Beynen (2020b) 'BeynenAC2020.Bakeddogfood', Reserch gate [Preprint].

Arvanitoyannis, I.S. and Kassaveti, A. (2008) 'Fish industry waste: Treatments, environmental impacts, current and potential uses', International Journal of Food Science and Technology, 43(4), pp. 726–745. doi:10.1111/j.1365-2621.2006.01513.x.

Bakshi, M.P.S., Wadhwa, M. and Makkar, H.P.S. (2016) 'Waste to worth: vegetable wastes as animal feed.', Cab Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, 11, pp. 1–26.

Bampidis, V. et al. (2021) 'Safety and efficacy of an additive consisting of xanthan gum produced by Xanthomonas campestris strains for all animal species (Biopolymer International)', EFSA Journal, 19(7). doi:10.2903/j.efsa.2021.6710.

Barbosa-Cánovas, G. V. et al. (2008) Water Activity in Foods: Fundamentals and

Applications, Water Activity in Foods: Fundamentals and Applications. doi:10.1002/9780470376454.

Barden, L. and Decker, E.A. (2013) ‘Lipid oxidation in low-moisture food: A review’, Critical Reviews in Food Science and Nutrition, 56(15), pp. 2467–2482. doi:10.1080/10408398.2013.848833.

Başer, Ö. and Yalçin, S. (2017) Determination of some quality characteristics in pet foods *, Ankara Üniv Vet Fak Derg.

Bellù, L.G. (2018) Food and Agriculture Organization of the United Nations Rome. Available at: www.fao.org/publications.

Burdett, S.W., Mansilla, W.D. and Shoveller, A.K. (2018) Article Many Canadian dog and cat foods fail to comply with the guaranteed analyses reported on packages, CVJ.

Burkhardt, S. (2019) Gateway to the Future Nonwood Lignin as a Binder for Pet Food. St. Louis, MO.

Caipang, C.M., Mabuhay-Omar, J. and Plasus, M.M. (2019) ‘Plant and fruit waste products as phytogenic feed additives in aquaculture’, AACL Bioflux, 12, pp. 261–268.

Campigotto, G. et al. (2020) ‘Dog food production using curcumin as antioxidant: effects of intake on animal growth, health and feed conservation’, Archives of Animal Nutrition, 74(5), pp. 397–413. doi:10.1080/1745039X.2020.1769442.

Cansu, Ü. and Boran, G. (2015) ‘Optimization of a Multi-Step Procedure for Isolation of Chicken Bone Collagen’, J. Food Sci. An, 35(4), pp. 431–440. doi:10.5851/kosfa.2015.35.4.431.

Charalampopoulos, D. (2018) ‘Food waste and by-products valorization’, in Food: The Vital Ingredient.

Chen, T., Jin, Y. and Shen, D. (2015) ‘A safety analysis of food waste-derived animal feeds from three typical conversion techniques in China', Waste Management, 45. doi:10.1016/j.wasman.2015.06.041.

Cheng, J.Y.K. and Lo, I.M.C. (2016) 'Investigation of the available technologies and their feasibility for the conversion of food waste into fish feed in Hong Kong', Environmental Science and Pollution Research, 23(8). doi:10.1007/s11356-015-4668-3.

Cohen, J.S. and Yang, T.C.S. (1995) 'Progress in food dehydration', Trends in Food Science and Technology. doi:10.1016/S0924-2244(00)88913-X.

Corsato Alvarenga, I., Aldrich, C.G. and Shi, Y.-C. (2021) 'Factors affecting digestibility of starches and their implications on adult dog health', Animal Feed Science and Technology, 282, p. 115134. doi:https://doi.org/10.1016/j.anifeedsci.2021.115134.

Dame-Korevaar, A. et al. (2021) 'Microbial health hazards of recycling food waste as animal feed', Future Foods. Elsevier B.V. doi:10.1016/j.fufo.2021.100062.

Dilruskshi H.N.N., J.B.P.A.& G.A.P. (2009) 'Formulation of dog food using locally available ingredients', Wayamba Journal of Animal Science, pp. 1–5.

Donadelli, R.A. et al. (2019) 'The amino acid composition and protein quality of various egg, poultry meal by-products, and vegetable proteins used in the production of dog and cat diets', Poultry Science, 98(3), pp. 1371–1378. doi:10.3382/ps/pey462.

Di Donfrancesco, B., Koppel, K. and Aldrich, C.G. (2018) 'Pet and owner acceptance of dry dog foods manufactured with sorghum and sorghum fractions', Journal of Cereal Science, 83, pp. 42–48. doi:10.1016/j.jcs.2018.07.011.

Dou, Z., Toth, J.D. and Westendorf, M.L. (2018) 'Food waste for livestock feeding: Feasibility, safety, and sustainability implications', Global Food Security. Elsevier B.V., pp. 154–161. doi:10.1016/j.gfs.2017.12.003.

Du, J. et al. (2020) 'Modeling and kinetics study of microwave heat drying of low grade manganese ore', Advanced Powder Technology, 31(7).

doi:10.1016/j.apt.2020.05.013.

Dwandaru, W.S.B. and Sari, E.K. (2020) ‘Chicken bone wastes as precursor for C-dots in olive oil’, Journal of Physical Science, 31(2), pp. 113–131. doi:10.21315/JPS2020.31.2.8.

Ferraretto, L.F., Shaver, R.D. and Luck, B.D. (2018) ‘Silage review: Recent advances and future technologies for whole-plant and fractionated corn silage harvesting’, Journal of Dairy Science. doi:10.3168/jds.2017-13728.

Garcia-Garcia, G. et al. (2017) ‘A Methodology for Sustainable Management of Food Waste’, Waste and Biomass Valorization, 8(6), pp. 2209–2227. doi:10.1007/s12649-016-9720-0.

Georganas, A. et al. (2020) ‘Bioactive Compounds in Food Waste: A Review on the Transformation of Food Waste to Animal Feed’, Foods, 9(3). doi:10.3390/foods9030291.

Girotto, F., Alibardi, L. and Cossu, R. (2015) ‘Food waste generation and industrial uses: A review’, Waste Management, 45. doi:10.1016/j.wasman.2015.06.008.

Gligorescu, A. et al. (2020) ‘Production and optimization of hermetia illucens (L.) larvae reared on food waste and utilized as feed ingredient’, Sustainability (Switzerland), 12(23). doi:10.3390/su12239864.

Glodde, F., Günal, M., Kinsel, Mary E., et al. (2018) ‘Effects of natural antioxidants on the stability of omega-3 fatty acids in dog food’, Journal of Veterinary Research (Poland), 62(1), pp. 103–108. doi:10.2478/jvetres-2018-0014.

Glodde, F., Günal, M., Kinsel, Mary E, et al. (2018) ‘G Effects of natural antioxidants on the stability of omega-3 fatty acids in dog food’, J Vet Res, 62, pp. 103–108. doi:10.2478/jvetres-2018-0014.

Goi, A., Simoni, M., et al. (2020) ‘Application of a handheld near-infrared spectrometer to predict gelatinized starch, fiber fractions, and mineral content of ground and intact extruded dry dog food', Animals, 10(9), pp. 1–13. doi:10.3390/ani10091660.

Goi, A., Manuelian, C.L., et al. (2020) 'At-line prediction of gelatinized starch and fiber fractions in extruded dry dog food using different near-infrared spectroscopy technologies', Animals, 10(5). doi:10.3390/ani10050862.

van Hal, O. et al. (2019) 'Upcycling food leftovers and grass resources through livestock: Impact of livestock system and productivity', Journal of Cleaner Production, 219. doi:10.1016/j.jclepro.2019.01.329.

Jan, R., Saxena, D.C. and Singh, S. (2016) 'Physico-chemical, textural, sensory and antioxidant characteristics of gluten - Free cookies made from raw and germinated Chenopodium (Chenopodium album) flour', LWT - Food Science and Technology, 71, pp. 281–287. doi:10.1016/j.lwt.2016.04.001.

Jereme, I.A. et al. (2016) 'Addressing the problems of food waste generation in Malaysia', International Journal of ADVANCED AND APPLIED SCIENCES, 3(8), pp. 68–77. doi:10.21833/ijaas.2016.08.012.

Jonathan Rivin, Zen Miller and Olivia Matel (2014) Using food waste as livestock feed. United States. Available at: www.epa.gov/smm/.

Kermavnar, T., Shannon, A. and O'Sullivan, L.W. (2021) 'The application of additive manufacturing / 3D printing in ergonomic aspects of product design: A systematic review', Applied Ergonomics. Elsevier Ltd. doi:10.1016/j.apergo.2021.103528.

Kritikos, G. et al. (2018) 'Quantification of vitamin D 3 in commercial dog foods and comparison with Association of American Feed Control officials recommendations and manufacturer-reported concentrations', Journal of the American Veterinary Medical Association, 252(12), pp. 1521–1526. doi:10.2460/javma.252.12.1521.

Kumoro, A.C. et al. (2010) 'EFFECT OF TEMPERATURE AND PARTICLE SIZE ON THE ALKALINE EXTRACTION OF PROTEIN FROM CHICKEN BONE WASTE', in.

Lalander, C. et al. (2019) ‘Effects of feedstock on larval development and process efficiency in waste treatment with black soldier fly (Hermetia illucens)’, Journal of Cleaner Production, 208. doi:10.1016/j.jclepro.2018.10.017.

Laso, J. et al. (2018) ‘Combined application of Life Cycle Assessment and linear programming to evaluate food waste-to-food strategies: Seeking for answers in the nexus approach’, Waste Management, 80. doi:10.1016/j.wasman.2018.09.009.

Mahssin, Z.Y. et al. (2021) ‘Hydrothermal liquefaction bioproduct of food waste conversion as an alternative composite of asphalt binder’, Journal of Cleaner Production, 282. doi:10.1016/j.jclepro.2020.125422.

Maire, M. et al. (2013) ‘Lipid oxidation in baked products: Impact of formula and process on the generation of volatile compounds’, Food Chemistry, 141(4), pp. 3510–3518. doi:10.1016/j.foodchem.2013.06.039.

Makkar, H.P.S. (2017) ‘Opinion paper: Food loss and waste to animal feed’, Animal. Cambridge University Press, pp. 1093–1095. doi:10.1017/S1751731117000702.

Makkar, H.P.S. (2018) ‘Review: Feed demand landscape and implications of food-not feed strategy for food security and climate change’, Animal, 12(8). doi:10.1017/S175173111700324X.

Manbeck, A.E. et al. (2017) ‘The effect of gelatin inclusion in high protein extruded pet food on kibble physical properties’, Animal Feed Science and Technology, 232, pp. 91–101. doi:https://doi.org/10.1016/j.anifeedsci.2017.08.010.

Manohar, R.S. and Rao, P.H. (2002) ‘Interrelationship between rheological characteristics of dough and quality of biscuits; use of elastic recovery of dough to predict biscuit quality’, Food Research International, 35(9), pp. 807–813.

Manzocco, L. et al. (2020) ‘Modeling the effect of the oxidation status of the ingredient oil on stability and shelf life of low-moisture bakery products: The case study of crackers', Foods, 9(6). doi:10.3390/foods9060749.

Martínez-Alvarez, O., Chamorro, S. and Brenes, A. (2015) 'Protein hydrolysates from animal processing by-products as a source of bioactive molecules with interest in animal feeding: A review', Food Research International, 73, pp. 204–212. doi:https://doi.org/10.1016/j.foodres.2015.04.005.

Mohd, N.A. et al. (2016) 'Properties and Characterization of Starch as a Natural Binder: A Brief Overview', J. Trop. Resour. Sustain. Sci, 4, pp. 117–121.

Motzer, E.A. et al. (1998) Quality of Restructured Hams Manufactured with PSE Pork as Affected by Water Binders, JOURNAL OF FOOD SCIENCE.

Murugesan, K. et al. (2021) 'Conversion of Food Waste to Animal Feeds', in Current Developments in Biotechnology and Bioengineering. doi:10.1016/b978-0-12-819148-4.00011-7.

Nursyafarinah, N. et al. (2019) 'Low temperature preparation of chicken bone-based porous carbon for lithium ion capacitor (LIC) cathode', in Journal of Physics: Conference Series. Institute of Physics Publishing. doi:10.1088/1742-6596/1191/1/012019.

Ockerman, H.W. and Hansen, C.L. (1988) Ellis Horwood Series in Food Science and Technology Animal By-Product-Processing.

Olivry, T. and Bexley, J. (2018) 'Cornstarch is less allergenic than corn flour in dogs and cats previously sensitized to corn', BMC Veterinary Research, 14(1). doi:10.1186/s12917-018-1538-5.

Pamela Schmutz and E. H. Hoyle (1999) DRYING FOODS, Clemson Cooperative Extension.

Pietrasik, Z. and Soladoye, O.P. (2021) 'Use of native pea starches as an alternative to modified corn starch in low-fat bologna', Meat Science, 171. doi:10.1016/j.meatsci.2020.108283.

Polo, J. et al. (2009) ‘The use of spray-dried animal plasma in comparison with other binders in canned pet food recipes’, Animal Feed Science and Technology, 154(3), pp. 241–247. doi:https://doi.org/10.1016/j.anifeedsci.2009.08.009.

Puotinen, C.J. (2005) Crazy About Coconut Oil ‘Virgin’ or unrefined, this healthy oil has multiple benefits for your dog. Available at: http://www.whole-dog-journal.com/cgi-bin/udt/sc2.display.ppv?client_id=wholedogjourna...

Rajeh, C. et al. (2021) ‘Food loss and food waste recovery as animal feed: a systematic review’, Journal of Material Cycles and Waste Management. doi:10.1007/s10163-020-01102-6.

Ramírez N., V., Peñuela S., L. and Pérez R., M. (2017) ‘Organic waste as an alternative feeds for pigs’, Revista de Ciencias Agrícolas, 34(2).

Rychen, G. et al. (2017) ‘Safety and efficacy of sodium and potassium alginate for pets, other non food-producing animals and fish’, EFSA Journal, 15(7). doi:10.2903/j.efsa.2017.4945.

Salemdeeb, R. et al. (2017) ‘Environmental and health impacts of using food waste as animal feed: a comparative analysis of food waste management options’, Journal of Cleaner Production, 140, pp. 871–880. doi:10.1016/j.jclepro.2016.05.049.

Sanderson, S.L. (2021) ‘Pros and Cons of Commercial Pet Foods (Including Grain/Grain Free) for Dogs and Cats’, Veterinary Clinics of North America - Small Animal Practice. W.B. Saunders, pp. 529–550. doi:10.1016/j.cvsm.2021.01.009.

Schreuders, F.K.G. et al. (2019) ‘Comparing structuring potential of pea and soy protein with gluten for meat analogue preparation’, Journal of Food Engineering, 261, pp. 32–39. doi:10.1016/j.jfoodeng.2019.04.022.

Siddiqui, Z. et al. (2021) ‘Recycling of food waste to produce chicken feed and liquid fertiliser’, Waste Management, 131, pp. 386–393. doi:10.1016/j.wasman.2021.06.016.

Singh, J. and Saxena, R.C. (2015) ‘Chapter 2 - An Introduction to Microalgae: Diversity and Significance’, in Kim, S.-K. (ed.) Handbook of Marine Microalgae. Boston: Academic Press, pp. 11–24. doi:https://doi.org/10.1016/B978-0-12-800776-1.00002-9.

Surendra, K.C. et al. (2020) ‘Rethinking organic wastes bioconversion: Evaluating the potential of the black soldier fly (Hermetia illucens (L.)) (Diptera: Stratiomyidae) (BSF)’, Waste Management. doi:10.1016/j.wasman.2020.07.050.

Surie (2014) ‘An exploratory study on the pet food purchasing behaviour of New Zealand consumers’, Lincoln University, pp. 1–77. Available at: https://researcharchive.lincoln.ac.nz/bitstream/handle/10182/6407/Surie_BCom%28Hons%29.pdf?sequence=3&isAllowed=y.

Theses, G. and Abd Razak, S. (2017) Scholar Commons Household Food Waste Prevention in Malaysia: An Issue Processes Model Perspective. Available at: http://scholarcommons.usf.edu/etdhttp://scholarcommons.usf.edu/etd/6990.

Tobie, C., Péron, F. and Larose, C. (2015) ‘Assessing food preferences in dogs and cats: A review of the current methods’, Animals, 5(1), pp. 126–137. doi:10.3390/ani5010126.

Tumuluru, J.S., Conner, C.C. and Hoover, A.N. (2016) ‘Method to produce durable pellets at lower energy consumption using high moisture corn stover and a corn starch binder in a flat die pellet mill’, Journal of Visualized Experiments, 2016(112). doi:10.3791/54092.

Vandevivere, L. et al. (2019) ‘Native starch as in situ binder for continuous twin screw wet granulation’, International Journal of Pharmaceutics, 571. doi:10.1016/j.ijpharm.2019.118760.

Virk, K.S. et al. (2019) ‘Development of Calcium Fortified Biscuits Incorporated with Chicken Slaughter House Byproducts and Evaluation of Their Palatability in Dogs’, Indian Journal of Animal Nutrition, 36(1), p. 77. doi:10.5958/2231-6744.2019.00013.6.

Wadhwa, M. and Bakshi, M. (2013) Utilization of fruit and vegetable wastes as livestock feed and as substrates for generation of other value-added products.

Wilson-Frank, C.R. and Hooser, S.B. (2018) 'Investigative Diagnostic Toxicology and the Role of the Veterinarian in Pet Food–Related Outbreaks: An Update', Veterinary Clinics of North America - Small Animal Practice. W.B. Saunders, pp. 909–915. doi:10.1016/j.cvsm.2018.07.001.

zu Ermgassen, E.K.H.J. et al. (2016) 'Reducing the land use of EU pork production: Where there's swill, there's a way', Food Policy, 58. doi:10.1016/j.foodpol.2015.11.001.

APPENDICES

Appendix A: Gantt Chart of FYP

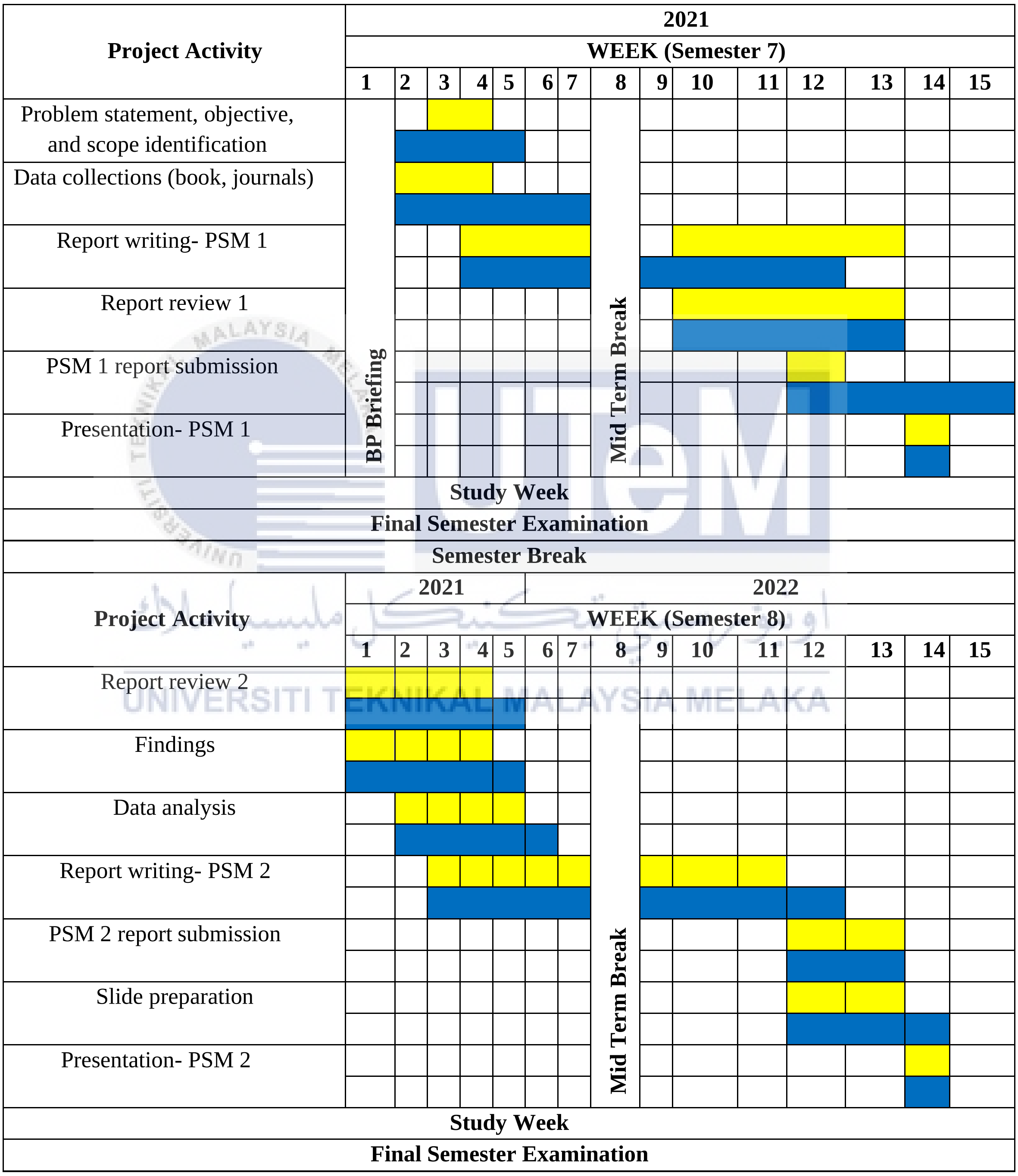


Figure 27: PSM 1 and PSM 2 Gantt Chart

Indicator Plan Actual