NUTRITIONAL COMPOSITIONS,

TOTAL PHENOLICS,

ANTIOXIDANT CAPACITIES, AND

STUDENTS' KNOWLEDGE LEVEL

ABOUT PLANT-BASED MEAT ITEMS

By

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ABSTRACT

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Recent trend of plant-based diet has led to the rise of plant-based meat (PBM) items. PBM refers to artificial meat products made from plant sources (e.g. soy protein, wheat gluten, legume proteins), designed to replicate the flavour, taste, and appearance of conventional meat. There are more and more plant-based products available in the market. However, there is a lack of study on the nutritional values of PBM in Malaysia. Also, there were no recent study on the knowledge level regarding PBM items among consumers, particularly undergraduate students in Malaysia. Therefore, proximate analysis, total phenolics, and antioxidant assays (DPPH and ABTS) were conducted on three local PBM dishes (n=3). The knowledge level on PBM items were assessed among UTAR undergraduate students as well. The result demonstrated significant difference ($p<0.05$) for ash and moisture content, in which ash ranged from 0.31 – 0.83% while moisture ranged from 51.40 – 62.70%. In terms of macronutrients, the PBM samples had high carbohydrates (25.31 – 37.25%), followed by high dietary fiber (1.00 – 8.50%), low fat (1.89 – 3.11%), and low protein (0.07 – 0.13%). The sample showed significant total phenolics content (1.00 – 3.17 (μg GAE/g), DPPH (AA%: 18.52 – 70.76%) and ABTS (AA%: 34.86 – 59.99%). The Pearson's correlation revealed strong correlation between total phenolics content with DPPH (r = 0.881) and ABTS (r = 0.952), indicating a strong association in which high phenolics contributed to high antioxidant level. Besides, based on Bloom's cut-off category, the results from questionnaires showed that UTAR undergraduate students had limited knowledge level on PBM items. Ultimately, this study may raise awareness about the need for more educational efforts to improve the consumers' understanding of PBM.

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I would like to begin by expressing my heartfelt gratitude to Universiti Tunku Abdul Rahman (UTAR) for not only providing me with the opportunity but also the necessary resources to successfully complete this final year project (FYP). UTAR has undeniably been a turning point in my life, one that I wholeheartedly cherish. Choosing to transfer to the dietetics course at UTAR three years ago remains the best decision I've ever made. I used to study another programme that I had no interest in, but now I find myself firmly anchored in my identity as a dietitian. My time at UTAR has taught me that it's not about enrolling in the best university in the world, but it’s more about the impact of the education it has had on me and my life.

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With the completion of this project, my final semester on campus also comes to an end. It had been a fruitful year. Thank you, everyone.

DECLARATION

I hereby declare that this final year project report is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTAR or other institutions.

ELISA BONG TSYR YIN

APPROVAL SHEET

This final year project report entitled **<u>"NUTRITIONAL COMPOSITIONS, TOTAL PHENOLICS, ANTIOXIDANT CAPACITIES, AND STUDENTS' KNOWLEDGE LEVEL ABOUT PLANT-BASED MEAT ITEMS"</u>** was prepared by ELISA BONG TSYR YIN and submitted as partial fulfillment of the requirements for the degree of Bachelor of Science (Hons) Dietetics at Universiti Tunku Abdul Rahman.

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PERMISSION SHEET

It is hereby certified that **ELISA BONG TSYR YIN** (ID No: **20ADB04785**) has completed this final year project report entitled "NUTRITIONAL COMPOSITIONS, TOTAL PHENOLICS, ANTIOXIDANT CAPACITIES, AND STUDENTS' KNOWLEDGE LEVEL ABOUT PLANT-BASED MEAT ITEMS" under the supervision of Dr. Chang Sui Kiat from the Department of Allied Health Sciences, Faculty of Science, and co-supervision of Dr. Ee Kah Yaw from the Department of Agricultural and Food Science, Faculty of Science. I hereby give permission to the University to upload the softcopy of my final year project report in pdf format into the UTAR Institutional Repository, which may be made accessible to the UTAR community and public.

Yours truly,

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(ELISA BONG TSYR YIN)

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LIST OF ABBREVIATIONS

PBM	Plant-Based Meat
TPC	Total Phenolics Content
TFC	Total Flavonoids Content
TAC	Total Antioxidant Capacities
DPPH	Diphenyl-1-picrylhydrazyl
ABTS	Azino-bis(3-ethylbenzothiazoline-6-sulphonic acid)
ACB	Avocado Charcoal Bun
CDT	Caviar Cappelli D’Angelo with Truffles
SBT	Steak de Boeuf with Truffle Sauce

CHAPTER 1

INTRODUCTION

1.1 Research Background

Human needs food. Initially, people eat for survival, subsequently, for the pleasure it brings. According to Tóth (2004), every person will consume a total of 1.5 tons of food per capita over their lifetime. Among all types of diet in the world, plant-based diet stands out, accounting for about 21.8% of global population (roughly 1,490 million of people) (Leahy, Lyons, and Tol, 2010). In Malaysia, there are a total of 1,185 vegetarian restaurants catering to nearly 27,000 diners daily. Also, Malaysia was ranked for the 3rd most vegetarian-friendly country globally in 2017 (Darmalinggam and Kaliannan, 2020). Along with the trend, plant-based meat (PBM) products emerged on the market to replicate the sensory experience of consuming animal-based meat. In the United States, the retail sales of PBM had been experiencing an impressive 18% year-over-year, which is six times outgrow the animal meat market (Clayton and Weston, 2020). Now, the availability of PBM products in the supermarkets has expanded significantly, amounting to five times the volume in 2015 (Curtain, and Grafenauer, 2019). PBM has been widely consumed around the world. In a study of Knaapila, et al. (2022), 84% of their respondents (from Germany, Finland, France, and UK) have sampled meat alternatives and/or consume on a regular basis. The PBM buyers are not limited to vegans, but also non-vegans or non-vegetarian that simply seeking for wholesome, sustainable, and cheap food choices (Mohamed, et al., 217). Interestingly, Davitt, et al. (2021) found that more than half of their respondents has eaten PBM while 86.4% of them identified themselves as non-vegetarians.

As the saying goes, “You are what you eat” and “illness comes in from the mouth”, these highlight the profound impact of food on human health. Food and dietary habits contribute nearly 40-60% of illnesses (Fehér, et al., 2004). Supporting this, a cohort study revealed that vegetarians had 24% lower rate of coronary heart disease mortality compared to omnivores (Satija and Hu, 2018). Scientific evidence further emphasizes that vegetarians experience reduced prevalence of hypertension, heart diseases, and cancer (Healey, 2012). Similar findings were observed in Malaysia, where vegetarian respondents showed lower rates of overweight and obesity, as well as improved blood pressure status when contrasted with non-vegetarians (Gan, et al., 2018). Besides, people consume PBM as a commitment for environmental sustainability (Knaapila, et al., 2022; Bakar, et al., 2023). However, there were debates around the sustainability of plant-based food products. Varela, et al. (2022) discussed the concept of “greenwashing” within the vegan food industry. This term refers to a deceptive marketing tactic used to label plant-based products as environmental-friendly or sustainable without actual actions to support these claims. A significant example of greenwashing was reported by Evans and Hodgson (2022) in the Financial Times, where Tesco faced criticism for greenwashing their Plant Chef burgers and other plant protein-based food. They promoted the idea of purchasing these products would have a positive impact on the planet, despite potential lack of actual sustainability efforts behind the scenes. In addition, individuals consume PBM for various other reasons, including religious beliefs, concerns for animal welfare, and economic considerations (Bakar, et al., 2023).

In terms of nutritional composition, PBM are claimed to have a relatively low saturated fat, low cholesterol content, well-balanced amino acid profile, and high dietary fibres. Some of them are also fortified with vitamins and minerals, aiming for a more comprehensive nutritional replacement (Van Vliet, et al., 2021; Zhou, et al, 2021; Swing, et al., 2021). Furthermore, the protein values are one of the key attributes that are often being compared to animal meat. Romao, et al. (2023) stated that the protein values varied according to the types of PBM with some showing lower level than others. Furthermore, Van Vliet, et al. (2021) found a wider variety and greater abundance of phenolic compounds (e.g. sulfurol, syringic acid, vanillic acid, and valeric acid) in PBM compared to ground beef, which may benefit human health by reducing oxidative stress and inflammation. Other metabolites in nutrient classes such as tocopherols (α, γ, and δ), phytosterols, and spermidine were found significantly higher in PBM as evidenced by these studies.

1.2 Problem Statements

In the market, plant-based meat (PBM) products have always been claimed to have advantageous nutritional profile, particularly in terms of their high-fibre, promising protein level, and low-fat content. In Sweden, the fibre was the most emphasized nutrient (68%), followed by protein and fat (particularly saturated fat) on the nutritional packaging of PBM (Bryngelsson, et al., 2022). Similarly, in the U.S., PBM product had been marketed for their high fibre, protein and fat content. For instance, common product's front-of pack claims include "25g of protein", "high in fibre", "cholesterol-free", "35% less fat than pork sausages", and more. Besides, certain PBM are claimed for their potential health benefits. In the U.S., packaging often features terms such as "healthy" "nutritious" and "wholesome". Some general health claims such as "Fibre helps to keep our digestive system healthy" "Soy protein helps to lower cholesterol and the risk for heart disease" were reported (Lacy-Nichols, Hattersley and Scrinis, 2021).

Although numerous studies have assessed the nutritional aspects of PBM items, majority of these studies have been conducted overseas (e.g. Sweden, U.S., U.K. and China). In contrast, in Malaysia, there were only a few related studies. For example, Sharima-Abdullah, et al. (2018) studied the nutritional compositions of imitation chicken nuggets particularly produced from chickpea flour. There were also numerous nutritional evaluation, however, on processed animal meat, instead of PBM. For example, Babji and Yusof (1995) focused on the chemical composition and nutritional evaluation of locally processed meat products in Malaysia. Others were comparative studies of the meat analogues within the same food category, like beef frankfurter (Nurul, et al., 2010), beef meatballs (Huda, et al., 2010), and fish balls (Nurul, et al., 2010). In addition, there were limited published article in Malaysia that study about the antioxidant capacities of PBM. In addition, the nutritional information of plant-based products also cannot be found on the Malaysian Food Database Composition website established by the Ministry of Health Malaysia. The lack of information hinders Malaysians from gaining insights into the locally available PBM offerings.

Without the access to reliable information of PBM, Malaysian consumers might face challenges in comprehending the principles of healthy eating and the diverse choices available in the market.

As such, this research seeks to bridge this information gap in terms of the nutritional composition and antioxidant capacities through proximate analysis and chemical reagent assays (DPPH and ABTS). Besides, there is a vegetarian stall on the campus of UTAR (Kampar), which previously located in Block D and now relocated in Block K. For convenient reason, it has gained significant popularity among the students as a preferred lunch place. Given the increase exposure to PBM consumption facilitated by this stall, a survey will be circulated to study the depth of knowledge among UTAR (Kampar) undergraduate students regarding this novel food items.

1.3 Significance of Study

This study primarily aims to study the nutritional composition of various plant-based meat (PBM) dishes through proximate analysis and chemical assays on the total phenolics content, total flavonoids content, and total antioxidant capacities. Besides, results of this study will reveal the knowledge level of consumers, particularly of the undergraduate students from UTAR (Kampar, Malaysia), on the PBM items. The knowledge level gives insight for restaurant owners or PBM manufacturers about their target customers' understanding regarding plant-based products. Hence, it also provides directions for future education in areas where there is a lack of understanding.

1.4 Objectives

1.4.1 General Objective

To investigate the nutritional compositions, total phenolics content (TPC), and total antioxidant capacities (TAC) of PBM items.

1.4.2 Specific Objectives

The specific objectives are as follows:

i. To determine the ash, moisture, protein, fat, dietary fibre, and carbohydrates in PBM products using proximate analyses.
ii. To determine the total phenolics content (TPC), total flavonoids content (TFC), total antioxidant capacity (TAC) in PBM products.
iii. To determine the correlation between TPC, TFC, and TAC in PBM items.
iv. To assess consumers' knowledge on PBM items among UTAR undergraduate students.

CHAPTER 2

LITERATURE REVIEW

2.1 What is Plant-based Meat?

According to Clayton and Weston (2020), plant-based meats are defined as meat products made up of plant sources. These meat-like products are produced to replicate the appearance, taste, texture, and nutrition of animal meat. Hence, they are often referred to as meat substitutes. Other similar terminologies are meat analogues, meat replacers, meat imitations, meatless meat, artificial meats, fake meats (Kyriakopoulou, Keppler, and van der Goot, 2021).

2.2 Development of Plant-Based Meat

Back in history, people have been consuming plant-based protein products as alternatives to animal meat since ancient civilizations (He, et al., 2020). In Asia, plant-based protein products are particularly popular in China and India, which can be attributed by their local culture rooted in Buddhism and vegetarianism. During Han Dynasty (206 BC to 220 AD) and Tang Dynasty (618 to 907 AD) in China, traditional plant-based products such as *tofu* (blocks of soybean curds) have been widely included as part of their daily diet (Bakhsh, et al., 2021). Such dietary practice was spread to Japan since Song and Tang Dynasty, which was integrated into local diet and developed into unique vegetarian culinary tradition (Bakhsh, et al., 2021; Ishaq, et al., 2022). Other common plant-based products are *tempeh* (fermented soybeans cake), *seitan* (wheat gluten), *Yuba* and *tofu* skin (bean curd sheet) (He, et al., 2020; Zhang, et al., 2021). In Western countries, soy and soy products are the primary meat substitutes in the early 1960s (Zhang, et al., 2021). Moreover, John Harvey Kellogg introduced nut- and cereal-based meat products such as “Nuttose” and “Protose” into the market. With the name of “vegetable meats”, it claimed to turn non-flesh foods into meat-like products with more health benefits (Bakhsh et al., 2021; Shprintzen, 2012). Also during 1960s, the concept of textured vegetable protein (TVP) or dry texturized vegetable protein was introduced. The main ingredients included soy protein (e.g. soy flour, soy protein concentrate (SPC), and soy protein isolates (SPI)), wheat gluten, and starches (Ishaq, et al., 2022; Zhang, et al., 2021). The manufacturing process involved spinning and extrusion, allowing the production of meat alternatives without any animal meat ingredients (Bakhsh, et al., 2021). He, et al. (2019) stated that the concept of TVP was further advanced into the plant-based meat products today.

Furthermore, with the end of World War II, there was a surge in meat consumption, leading to significant agricultural expansion and animal farming (Bakhsh, et al., 2021). To cope with the rising demand of meat, significant progress were made in the production and packaging industry, as well as the application of plant protein ingredients in developing meat alternatives products to satisfy meat eaters (Ishaq, et al., 2022). Until modern era, the Burger King introduced their first plant-based burger in 2002, which was the first step of bringing plant-based meat burger entered the fast-food chain (Bakhsh, et al., 2021). In the last decade, there has been a rise in consciousness about sustainability, animal welfare, health and well-being, resulting in a shift in diet preferences from conventional meat to plant-based meat (He, et al., 2019). Food company such as Impossible Foods and Beyond Meat are leading corporations with the newest generation of PBM products that mimic animal meat with similar textures, smells, and bloody colours. Their plant-based burgers represent about 15% of total burger sales globally (Bakhsh, et al., 2021). Besides, the world's largest home furnishings retailer, IKEA, has started selling plant-based hotdogs that are cheaper than animal-based hotdogs. Until 2019, their plant-based hotdogs contributed 8% of annual hotdog sales worldwide (Peacock, 2023). To explore more plant-based ingredient options, the food industry is also experimenting with different potential protein ingredients such as insect protein, mycoproteins, and microalgae in formulating plant-based meat (Zhang, et al., 2021).

2.3 Common Plant Proteins for Plant-Based Meat

There are various forms of plant-based meat products exist in the market. For example, burgers, sausages, mince, chicken, and seafood, as classified by Curtain and Grafenauer (2019). The main ingredients in these PBM products are soy protein, wheat gluten, legume proteins, seed proteins, and other plant proteins (peanut, potato, zein, hemp). Before the production, selection of plant protein often influenced by the protein availability, yield of the crops, and protein extraction potential (Kyriakopoulou, Keppler, and van der Goot, 2021).

2.3.1 Soy Protein

Soy protein can be categorised into several types of usable ingredients, including soy isolate (~90% protein), soy concentrate (~70% protein), soy flour (~43-56% protein), and spray-dried soymilk powder (>45% protein). These distinct soy ingredients each offer different functionality when incorporated into PBM formulations. For instance, soy isolates are valued for their excellent solubility and gelling properties, while soy concentrate has good texturization properties. Soy flour has good water binding capacity and fat retention abilities, while soymilk powder demonstrates high solubility and effective emulsification (Curtain and Grafenauer, 2019). Soy protein has been a popular ingredient in the formulation of PBM items such as Impossible Burger. After oil extraction, the soy meals collected are rich in protein content, featuring a well-balanced amino acid profiles, cost-effectiveness, and specific functionalities like strong gelling properties. These attributes are favourable to produce protein-rich food ingredients that are used in PBM products (Kyriakopoulou, Keppler, and van der Goot, 2021). However, the application of soy protein has its limitations, arising from the health concern on the antinutritional compounds (e.g. phytates, tannins, and protease inhibitors), as well as the environmental issues linked to the deforestation for crop production (Adeyerno and Onilude, 2013; Fehlenberg, et al., 2017)

2.3.2 Wheat Gluten

Wheat gluten is a by-product from the wheat starch production, characterized by the insoluble protein residue remaining from the removal of other soluble components. The average protein content in wheat gluten isolate is approximately 75% to 80%. Similar to soy protein, it is cost-effective and is frequently chosen as a primary ingredient for PBM due to its capability to function as both a binder and structuring agent (Kyriakopoulou, Keppler, and van der Goot, 2021). A significant example in the market is the incorporation of wheat gluten in products like the Beyond Meat Chicken Nuggets (Bakhsh, et al., 2021a). Nevertheless, it is important to note that individuals with gluten intolerance should avoid products containing wheat gluten. Consumption by such individuals often results in gastrointestinal discomfort (e.g. bloating, abdominal cramps, diarrhea) as a consequence of wheat allergy or Celiac disease (Thakur, 2019)

2.3.3 Legume Proteins

Legume proteins offer viable alternatives to soy protein and wheat gluten, including a range of legumes such as peas, chickpeas, fava beans, mung beans, peanuts, lentils, and other bean varieties. Among these legumes, pea protein stands out and has been widely used in commercial PBM items such as Beyond Meat burger patties (16% of pea protein in overall ingredients) (Kyriakopoulou, Keppler, and van der Goot, 2021). Yellow peas are the most acclaimed ingredients, which attributed to their high protein content (~85% of protein), availability, and cost-effectiveness. The main component, pea globulins (legumins and vicilins), contributes 70-80% of proteins and its ability to form gel structure (Masiá, et al., 2022). Similarly, mung bean and chickpea demonstrate good gelling function. However, lentil, lupine, and fava bean protein presented comparatively weaker gelling capacities. Nonetheless, legumes protein, such as pea protein, tend to have a weaker structure in comparison to soy protein, leading to a weaker cohesive and fibrous texture. Hence, hydrocolloids are often incorporated into the PBM products to address the texture gap and achieve a more realistic meat-like consistency (Bascuas, et al., 2021). In addition, it is essential to highlight that food items containing legume proteins may possess risk for individuals with legumes allergies, with peanut allergies manifesting the highest prevalence among all legumes (Cox, Eigenmann, Sicherer, 2021).

2.3.4 Others

In addition to soy, wheat glute, and legume proteins, other plant-based protein derived from oilseeds such as rapeseed, sunflower, and quinoa, have also gained attention in the food industry. Much like soy protein, many of these proteins are by-products of the oil industry, leading to cost-effectiveness. Functionally, they consistently exhibited strong emulsion stability, which is comparable to soybean protein isolates (Kyriakopoulou, Keppler, and van der Goot, 2021). However, their limitation would be the presence of antinutritional factors (e.g. polyphenols) in some of the oilseeds, which interferes the absorption of protein in the intestines. On top of that, research has indicated that sunflower protein showed absence of antinutrients along with minimal allergenicity, making it a potentially prominent option in the future (Arrutia, et al., 2020). Other protein-rich sources, including hemp, potato, and corn zein, can be alternative sources of plant protein in PBM items (Shaghaghian, et al., 2022). Although some plant protein isolates and concentrates are not available in the market yet, their potential functionality suggests a promising capacity to replace soy in PBM formulations.

2.4 Proximate Analysis

2.4.1 Ash

Ash content represents inorganic substances in the food sample, including minerals such as sodium, potassium, and calcium (Kamau, et al., 2020). In most studies, PBM products showed higher ash content. For example, in the study conducted by Bakhsh, et al. (2021a), the ash content (%) of PBM products (3.23±0.144) was significantly higher than the beef (1.55±0.29) and pork patties (1.51±0.25). Also, Ghangale, et al. (2022) demonstrated a significant increase in the ash content in PBM samples, which was explained to be due to the excess minerals, starch, and fibre.

2.4.2 Moisture

Generally, current studies have shown that the moisture content of plant-based meat products are higher than that of animal meat products. According to Ghangale, et al. (2022), the plant-based meat analogue samples, M_1 and M_2 showed higher moisture content, which was 55.16% and 77.61% respectively, compared to the control sample of meat patty (48.73%). The main ingredients of the PBM analogues were jackfruit, pea protein isolates, cashew nuts, flax seed, and xanthum gum. The dietary fibres in plant-based ingredients, especially jackfruit and flaxseed flour, bind to water, causing less moisture loss during the drying process of proximate analysis. Furthermore, Bakhsh, et al. (2021a), burger patties mixed with plant-based ingredients and methylcellulose showed significantly higher moisture content than beef and pork patties. They explained that methylcellulose formed thermal gelation when temperature increased. The adhesive layer prevents the food product to loss less moisture during the heating process, resulting in the ability to retain more water within the food.

2.4.3 Lipid

Bakhsh, et al. (2021a) stated that PBM products in the market has average fat content manufactured from vegetable and cereal ingredients. In the study of Ghangale, et al. (2022), the fat content of PBM analogue was in the range of 3.51 – 10.99%, while the control (animal meat) was 4.3%. They explained that the fat content was highly dependent on the ingredients. For instance, higher fat percentage was found in the products with higher amount of cashew nut flour. Bakhsh, et al. (2021b) mentioned that traditional meat analogues were generally low in fat and protein. However, PBM products in current market contain substantially more fat and protein due to various food additives.

2.4.4 Protein

In most studies, PBM products showed lower protein content compared to animal meat products. Bakhsh, et al. (2021a) concluded a higher protein in beef and pork protein compared to PBM analogue control sample. Another study by Bakhsh, et al. (2021b) also showed a higher protein content in the control (beef) compared to PBM products made of texture vegetable protein and texture isolate soy protein. Romão, et al. (2023) showed the comparison of protein content between meat products and their vegan substitutes. Generally, meat products from animal sources have higher protein content than that of vegan meat. For example, meat burger (17.6) and vegan burger (13.15); meat balls (16.5) and vegan meat balls (13.75); mined meat 919.0) and vegan minced meat (14.9); Chicken cutlets (18.47) and vegan chicken cutlets (24.0); Cold cuts (16.5) and vegan cold cuts (9.5); Seafood (24.0) and vegan seafood (8.9); Cutlets (31.9) and vegan cutlets (10.1). Besides, PBM products made of cereal ingredients have lower protein content, in which the digestibility of cereal protein is also lower (Abdullah, et al., 2022).

2.4.5 Dietary Fibre

Generally, PBM products contain higher amount of dietary fibre. Bakhsh, et al. (2021a) showed that the PBM samples contained 4 – 5% of fibre, while the animal meat products have nearly zero fibre. The higher amount of fibre are mainly contributed by the plants and polysaccharides in the formulation. Similar results were also reported by Romão, et al. (2023), in which they compared various meat products and their plant substitutes. For example, chicken cutlets has no fibre, while the vegan chicken cutlets contain 5.84g of fibre. Processed food like chicken nuggets contain 1g of fibre while vegan chicken nuggets contain 5.1g of fibre. Bakhsh, et al. (2021b) also mentioned that the PBM analogues have higher fibre, with the texture vegetable protein ranked the highest value due to the plant-based ingredients. The fibre also improved the textural and sensory sensation.

2.4.6 Carbohydrates

Previous studies showed that PBM products have higher carbohydrate content compared to animal products. As shown in the study conducted by Romão, et al. (2023), vegan burger patty had 11.13g of carbohydrates while meat burger patty did not contain any carbohydrates. Similar result was shown for the comparison between minced meat, cutlets, cold cuts, and their respective vegan substitutes. Ghangale, et al. (2022) explained that the plant-based ingredients used in their samples such as jackfruit and cashew nut flour increased the PBM products' carbohydrates. In addition, inclusion of cereal-based ingredients in plant-based meat analogues also resulted in higher carbohydrate content (Abdullah, et al., 2022).

2.5 Total Phenolics Content (TPC) and Total Flavonoids Content (TFC)

Recent studies have shown that PBM products generally have higher total phenolics and flavonoids content compared to conventional meat analogues. Abdullah, et al. (2022) concluded that the difference in TPC is mainly due to the ingredients. PBM products utilises high amount of soybeans in the production, which is a good source of phenolic and flavonoid compounds. Bohrer (2019) stated that unprocessed soy protein can darken the meat and produce bitter flavour in the product. Hence, soy protein isolates are a better option in formulating the product recipe. Moreover, Van Vliet, et al. (2021) compared TPC between PBM alternatives and beef. Apparently PBM has higher TPC due to the abundance of phenols and phytosterols such as beta-sitosterol, campesterol, and stigmasterol. Palanisamy, et al. (2019) observed that the higher the amount of

Spirulina platensis (a type of algae) flour in the PBM, the higher the TPC and TFC were observed.

2.6 Total Antioxidant Capacity (TAC)

Total antioxidant capacities are determined by two common types of assays: 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging assay and 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) diammonium salt (ABTS) free radical scavenging assay. In the study conducted by Abdullah, et al. (2022), Hungarian sausage analogue ranked the highest in DPPH and ABTS scavenging assay among other meat analogues and conventional processed meat. The result was attributed to the ingredients (wheat, soy, ground barley, oatmeal, sunflower oil, garlic, ground pepper, salt, spices), which contained a high amount of oatmeal. Oat is packed with antioxidant properties, including avenanthramides, phenolic compounds, phytic acid and vitamin E (tocols), as flavonoids and sterols. Besides, Xing, et al. (2022) showed that the DPPH scavenging rate of all PBM samples have exceeded 20%, while that of other meat sample was only between the range of 3.2 – 5.8%. Li, et al. (2022) concluded that the DPPH and ABTS scavenging rates increased with the rice bran supplemental level in plant-based simulated meat. Under food processing, the polyphenolic hydroxyl of rice brain binds to the soybean protein isolate, forming a stable complex that can improve the antioxidant capacity to withstand extreme conditions during food processing (e.g. high temperature, pressure, shear.

2.7 Consumers' Knowledge on Plant-Based Meat Items

Various studies have shown that consumers' knowledge towards plant-based meat items impacts their purchase decisions. Product information, especially nutritional facts of a particular products is important to affect their purchase tendencies. Wang, et al. (2022) concluded that the knowledge on PBM items among respondents in Beijing, China is still low, as only 3.42% of respondents answered correct in all the questions. However, their buying intentions increased after the nutrition information of PBM products were given. Similar study were conducted by Shen and Chen (2020) in Taiwan, where they concluded that consumers' knowledge about PBM product has significant positive impact on their purchase intentions. In specific, higher level of product knowledge leads to higher purchase intention. In addition, according to Font-i-Furnols and Guerrero (2022), transparency and knowledge allow consumers to be aware of the product properties, advantages, and disadvantages. Therefore, it facilitates consumers to make informed decisions. All in all, current studies suggested that information impacts consumer's knowledge and understanding, which is closely related to consumers' purchase interest.

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

A total of three dishes (n=3) made with plant-based meat products were used as the samples. All of them were prepared by vegan restaurant in Ipoh, Perak, Malaysia. The main ingredients and plant-based meat items used in the dishes are shown in Table 3.1.

Table 3.1: Main ingredients of plant-based meat dishes.

Name of Dishes	Ingredients
Avocado Charcoal Bun (ACB)	Charcoal bun, beyond meat patty, avocado mayo dressing, tomato slices, and baby spinach.
Caviar Cappelli D'Angelo with Truffles (CDT)	Angel hair, parsley flakes, black pepper course, plant-based whole truffle, and plant-based caviar.
Steak de Boeuf with Truffle Sauce (SBT)	Beef patty, carrot slices, sauté mushroom, bay leaves, dried oregano, grilled sweet corn, black pepper course, white truffle sauce, and French fries.

3.2 Sample Preparation

Sample preparation includes sample processing and homogenization. All ingredients in each dish were cut and chopped into smaller pieces. Then, they were mixed in a countertop blender (PHILIPS Blender Core, Series 5000, Netherlands) until a soft, pureed texture is formed. The homogenized samples were stored separately in a resealable storage bag (MR DIY, Malaysia) and kept in a chest freezer at -20°C prior to analysis.

3.3 Sample Extraction

The homogenised PBM samples (3g) were extracted by adding 15ml of aqueous methanol at a ratio of 1:5 and agitated at 150 rpm at room temperature (25°C) for 60 min using a benchtop orbital shaking incubator LM-450D (Yihder Co., Ltd., Taiwan). The samples were centrifuged at 4500rpm for 15 mins using an universal refrigerated benchtop centrifuge 3-18KS (Sigma, Germany). The supernatant in each sample tube was collected. The residues were re-extracted with the same ratio of aqueous solvent, followed by agitation and centrifugation. The supernatant was collected again in a media bottle and stored in chest freezer at -20°C prior to analysis.

3.4 Proximate Analysis

All proximate analysis were carried out based on the standard procedures stated in the Association of Official Agricultural Chemists (AOAC, 1995).

3.4.1 Determination of Ash Content

The ash content in PBM sample was determined by using the dry-ashing method. Porcelain crucibles were heated in a muffle furnace LT-14 (Nabertherm, Germany) at 550°C for 15 minutes and cooled in desiccator for 30 minutes. The empty crucible with lid was weighed and recorded as A_0. The samples were weighed to 4g and recorded as B. The samples were added into the crucible and brought to char with the aid of magnetic hot plate stirrer RH Basic-2 (IKA, Australia) at maximum temperature of 310°C in a fume hood. After the sample was thoroughly charred, the crucibles and their content were heated in muffle furnace at 550°C for 8 hours or overnight until the content turned light grey or white ashes. Then, the crucibles were cooled in desiccator for 30 minutes. The crucibles (with the lids and contents) were weighed and recorded as A_1. The ash content in the sample was calculated by using the formula below:

$$\text{Ash content, \% by weight} = \frac{A_1 - A_0}{B} \times 100 \qquad (1)$$

3.4.2 Determination of Moisture Content

The moisture content in PBM sample was determined by using moisture analyser MX-50 (A&D Co., Ltd., Japan). The machine was pre-set to adjust its accuracy (high accuracy), temperature (105°C), and measurement unit (moisture content sample). A piece of aluminium moisture weighing dish were placed in the machine, followed by a piece of glass fibre sheet. Glass fibre sheet was used to accelerate vaporisation of moisture, resulting lower duration and higher precision of the procedure. As the machine was set to zero, 10g of PBM sample was weighed and spread on the fibre glass evenly. Then, the moisture analyzer was started to run for 1-2.5 hours, in which the duration depends on the moisture level of samples. As the analysis completed, the moisture content (%) was obtained from the display screen and recorded.

3.4.3 Determination of Lipid Content

The crude lipid/fat content of samples was measured by using Soxhlet extraction method in the SOXTHERM rapid extraction system (6-place) and its respective software, Soxtherm® Manager (Gerhardt, Germany). Before the extraction, three boiling stones were inserted into the extraction beaker. A total of six extraction beakers were prepared in the same way. Then, they were preheated in a drying oven at 105°C for 1 hour, followed by cooling down in a desiccator for another 1 hour. Each extraction beaker was weighed and recorded as M_1. PBM sample was weighed to 5g on a filter paper and recorded as M_0. The filter paper was folded into funnel shape and inserted into a thimble. A piece of cotton wool was placed on top of the sample to cover it. The thimble was placed in a thimble holder and inserted into an extraction beaker. The solvent, petroleum ether (90ml) was added into the extraction beaker. All six extraction beakers were inserted into the Gerhardt innovative SOXTHERM rapid extraction system (6-place) for 2.5 hours. After the extraction was done, the thimble and thimble holder were removed from the beaker and placed in drying oven at 105°C for 1 hour, followed by cooling in desiccator for 1 hour. Lastly, the extraction beaker (without thimble and thimble holder) was weighed and recorded as M_2. The fat content in sample was calculate by using the formula below:

$$\text{Crude fat (\%)} = \frac{M_2 - M_1}{M_0} \times 100 \qquad (2)$$

3.4.4 Determination of Protein Content

The protein content in PBM sample was determined by using Kjeldahl method in the Speed Digester K-436 (BUCHI, Switzerland) and Scrubber K-415 (BUCHI K, Switzerland). The speed digester was preheated at 470°C for 10-15 minutes with the Scrubber turned on prior the analysis. To prepare the sample tube, the samples were weighed 2g and added into the digestion tubes. Catalyst (7g potassium sulfate (K_2SO_4) + 0.8g copper sulfate ($CuSO_4$) and 20mL of 98% concentrated sulfuric acid (H_2SO_4) were added into the digestion tube in the fume hood. One digestion tube was left as empty blank without any sample added. The prepared sample tubes were installed into the speed digester and digested at 470°C for 2 hours, or until the content in all tubes had turned into clear green solution. The rack of digestion tubes was cooled down to below 40°C (around 60 minutes).

The distillation process was performed in the Distillation Unit K-355 (BUCHI, Switzerland). The distillation unit was preheated with empty sample tube and empty receiving vessel for 2 minutes. After completing the preheating step, the cooled sample tube was inserted into the distillation unit and added with 40ml of distilled water and 60ml of 32% sodium hydroxide (NaOH). A conical flask was filled with receiving solution, which were 25ml of 4% boric acid and 2 drops of colour indicator (20mg of methyl red and 100mg of bromocresol green dissolved in 100ml 95% ethanol) and placed at the receiving vessel. The distillation was conducted for 4 minutes. The receiving solution turned from pink to pale blue green. The content in the digestion tube was discarded and cleaned in the distillation unit for another 2 minutes. Same procedures were repeated for the other sample tube. The solution in the receiving flask was titrated with 0.25M sulphuric acid, until it turns from blue to pale pink. The volume of acid used were recorded and used to calculate the protein content in PBM sample using the following formula:

$$\%N = \frac{[(V(1) - V(B1) \times F \times c \times f \times M(N)]}{m \times 1000} \times 100\% \quad (3)$$

$$\%P = \%N \times PF \quad (4)$$

V(1) = consumption of titrant, sample (mL)

V(B1) = average consumption of titrant, blank (mL)

F: molar reaction factor (1=HCl, 2 = H_2SO_4)

c: concentration of titrant (mol/L)

f: factor of titrant

M(N): molecular weight of N (14,007g/mol)

m: sample weight (g)

1000: conversion factor (mL in L)

PF = protein factor

%N = % of weight of N

%P = % of weight of protein

3.4.5 Determination of Total Fibre Content

The crude fibre content in PBM sample was determined by using the manual FIBREBAG Gerhardt Analytical Systems (Gerhardt, Germany). For sample preparation, fibre bags were dried in drying oven ED115L (Binder, Germany) at 105°C for 1 hour and cooled in desiccator for 30 minutes. The fibre bags were weighed and recorded as M_1 (for samples) and B_1 (for blank). The PBM samples were weighed 2g and recorded as M_2.

M_1 = Fibre bag (g)

B_1 = Blank value of empty fibre bag (g)

M_2 = Initial sample weight (g)

The glass spacers were inserted into the fibre bag, followed by inserting the samples. Then, the carousel was loaded with fibre bag and inserted into a beaker.

For digestion, 360ml of 0.13mol/L H_2SO_4 were added into the beaker loaded with carousel and fibre bag. The carousel was rotated for about 1 minute to mix the H_2SO_4 with the content. The beaker was placed on the preheated hot plate and brought to boil (took about 3-5 minutes) and the heat was reduced to obtain gently simmering. After 30 minutes, the beaker was removed from the hot plate. The solution and solutes in the beaker were discarded. The carousel was rinsed with hot water for several times. The digestion procedure was repeated by substituting the H_2SO_4 with 360ml of 0.23mol/L NaOH. The beaker was brought to boil and reduced to simmer for another 30 minutes.

As the digestion completed, the fibre bags were removed from the glass spacer and wiped dry with fibre-free tissues. These fibre bags were inserted into the pre-ashed crucible (pre-ashed at 600°C for 30 minutes in muffle furnace and 105°C for 30 minutes in drying oven). The crucible loaded with fibre bags were dried at 105°C for four hours or overnight. Then, they were cooled in desiccator for 30 minutes. Then, they were weighed and recorded as the following:

M_3 = Incinerating crucible and dried fibre bag of samples after digestion (g)

B_3 = Incinerating crucible and dried fibre bag of blank value after digestion (g)

For sample incineration, the crucible loaded with fibrebag were incinerated in muffle furnace at 600°C for 4 hours / overnight, followed by drying in oven at 105°C for 30 minutes. After cooling off in desiccator for 30 minutes, the crucibles were weighed and recorded as followed:

M_4 = Incinerating crucible and ash of sample (g)

B_4 = Incinerating crucible and ash of blank value (g)

After obtaining the values, the crude fibre (%) was calculated using the following formula:

$$\% \, Crude\ Fibre = [(M_3 - M_1 - M_4) - (B_3 - B_1 - B_4)] \times \frac{100}{M_2} \quad (5)$$

$$Blank = B_3 - B_1 - B_4 \quad (6)$$

3.4.6 Determination of Carbohydrates

The carbohydrate content in PBM sample was estimated using the equation:

$$Total\ carbohydrate\ (\%)$$

$$= 100\% - (\%MC + \%F + \%P + \%A + \%CF) \quad (7)$$

MC = Moisture content

F = Fat

P = Protein

A = Ash

CF = Crude fibre

3.5 Determination of Total Phenolics Content (TPC)

Total phenolics content (TPC) in PBM sample was determined using the Folin-Ciocalteau method described by Ee, et al. (2018) with slight modification. Firstly, 100 µL of samples with concentration at 100 mg/mL was mixed with 200 µL Folin-Ciocalteu reagent. The mixture was vortexed and incubated in the dark for 10 minutes at room temperature. Then, 1 mL of 7.0% sodium carbonate (Na_2CO_3) was added into the mixture and kept in the dark for 30 minutes. Absorbance of the mixture was read at wavelength 765 nm using the GENESYS 20 UV-vis spectrophotometer (Thermo Scientific, United States). A standard curve of gallic acid (0-100 µg/mL in 80% (v/v) methanol) was $y = 0.0166x + 0.0322$ ($R^2 = 0.9989$). TPC was expressed as milligram of gallic acid equivalent (GAE) per gram of sample.

3.6 Determination of total flavonoids content (TFC)

Total flavonoids content (TFC) in PBM sample was determined using the colorimetric method described by Ee, et al. (2019) with slight modification. Firstly, 250 µL of samples with concentration at 125 mg/mL was mixed with 1.25mL of distilled water and 75µL 5% (*w/v*) of sodium nitrite solution. The mixture was vortexed and kept in the dark for 6 minutes at room temperature (25 °C). After that, 0.3 mL 10% (*w/v*) of aluminium chloride hexahydrate solution was added into the mixture, which was allowed to react for another 6 min. Then, 1.0 mL of 1 M sodium hydroxide solution was added and the mixture was further incubated for 10 mins. The absorbance of the mixture was read at 510 nm. A standard curve of quercetin (0-100 µg/mL in 80% (v/v) methanol) was $y = 0.0007x + 0.0211$ ($R^2 = 0.9944$). TFC was expressed as milligram of quercetin equivalent (QE) per gram of sample.

3.7 Determination of Antioxidant Activity

3.7.1 2,2-diphenyl-1-picrylhydrazyl (DPPH) Free Radical Scavenging Assay

DPPH radical scavenging activity of PBM sample was determined based on a method described by Hiew, et al. (2021) with slight modification. 1 mL of extracted sample was mixed with 1.4 mL of DPPH solution (0.1 mM in 80% (v/v) methanol) in a test tube. The mixture was incubated in the dark at room temperature for 20 min prior to reading the absorbance at 517 nm against methanol blank. DPPH radical scavenging activity of the sample extract was calculated based on the equation below:

$$DPPH\ radical\ scavenging\ activity\ (\%) = \frac{A_{control} - A_{sample}}{A_{control}} \times 100\% \quad (8)$$

Trolox solution (0-16 µg/mL in 80% (v/v) methanol) was prepared. Antioxidant activity was expressed as milligram of Trolox equivalent (TE) per gram of dry extract. The results were measured as the IC_{50} value (inhibitory concentration) from the graph plotting inhibition percentage against extract concentration.

3.7.2 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) diammonium salt (ABTS) Free Radical Scavenging Assay

ABTS free radical scavenging assay of PBM sample was determined based on a method described by Wong, et al. (2014). Firstly, 5 ml of 7 mM ABTS was mixed with 88 µl of 140 mM potassium persulfate and kept in dark for 16-18 h at room temperature to allow complete generation of ABTS radical cation ($ABTS^{\bullet+}$). The mixture was then diluted with 80% methanol in order to obtain an absorbance of 0.70 ±0.05 when measured using the spectrophotometer at 734 nm. PBM sample (100 µl) was mixed with 1 ml of the ABTS reagent. The mixture was vortexed and incubated for 6 min at room temperature before the absorbance was measured at 734 nm against methanol blank. Distilled water (100 µl) was used as control. ABTS free radical scavenging activity of the sample extract was calculated based on the equation below:

$$ABTS\ radical\ inhibition\ ability\ (\%) = \frac{A_{control} - A_{sample}}{A_{control}} \times 100\% \quad (9)$$

Trolox solution (0-20 µg/mL in 80% (v/v) methanol) was prepared. Antioxidant activity was expressed as milligram of Trolox equivalent (TE) per gram of dry extract. The results were measured as the IC_{50} value (inhibitory concentration) from the graph plotting inhibition percentage against extract concentration.

3.8 Statistical Analyses

All data from proximate analyses, TPC, TFC, DPPH, and ABTS were expressed as mean ± standard deviation and were statistically analyzed using the SPSS statistical software version 27 (SPSS Inc., Chicago, Illinois, USA). All analysis were done in duplicate. One-way analysis of variance (ANOVA) and Tukey's test were used to compare means among groups. Pearson correlation test was used to assess the relationships between TFC, TPC, DPPH, and ABTS. The significance level was set at $p < 0.05$. The correlation coefficient was classified based on the categorisation stated by (Schober, Boer, and Schwarte, 2018).

3.9 Consumers' Knowledge on Plant-Based Meat (PBM) Item

3.9.1 Ethical Considerations

The survey was ethically approved by the UTAR Scientific and Ethical Review Committee (as attached in Appendix A). Prior to administering the questionnaire, description of the questionnaire was provided and the respondents' consent were obtained on the first page. All respondents were required to agree to participate in this study by clicking "Yes" in the informed consent section to indicate their voluntary participation. Otherwise, their responses will not be considered. All information was kept confidential and used solely for this research. In addition, details of the study were explained verbally as well, including the purpose of the study, confidentiality, and privacy policy.

3.9.2 Study Design and Study Platform

A descriptive, cross-sectional study was carried out from March 2023 to June 2023, targeting local undergraduate students in Universiti Tunku Abdul Rahman (UTAR). This study adhered to the guidelines of the Personal Data Protection Act of 2010 and received approval from the UTAR Scientific and Ethical Review Committee (Ref: U/SERC/62/2023). To ensure the research's efficiency, a convenience sampling method was employed to collect the data. The primary assessment tool utilized was a self-administered online questionnaire via Google Form.

3.9.3 Inclusion and Exclusion Criteria

The sampling subjects were Malaysian undergraduate students age 18-30 who were studying in Universiti Tunku Abdul Rahman (UTAR) Kampar, Perak at the time of data collection. However, participants were excluded if: (1) They were not UTAR students; or (2) They were foundation or postgraduates students; or (3) They disagreed to the privacy policy; or (4) They submitted incomplete responses.

3.9.4 Study sample

The sample size was calculated using the Cochran's Formula (Cochran, 1977) as below:

$$n = \frac{z^2 p(1-p)}{d^2} \tag{10}$$

Where,

n = sample size

z = statistics for a level of confidence (i.e. 1.96 for 95% confidence level)

p = expected prevalence or proportion

d = precision (i.e. 0.05)

$$n = \frac{1.96^2 \times 0.11(1-0.11)}{0.05^2} \tag{11}$$

$$= 150.44$$

$$\approx 151$$

According to Rakuten Insight (2022), approximately 11% of the respondens stated that they have consistently consumed plant-based meat products as alternative to animal-based food. Therefore, using the 11% as proportion (p), the sample size required in this study with 95% confidence level and precision of 0.05 was 151 students.

$$151 \times \frac{110}{100} = 165 \text{ students} \tag{12}$$

Considering a 10% for incomplete responses and drop-out rate, the final sample size calculated was 165 students.

3.9.5 Questionnaire

An online questionnaire was developed and modified from the survey applied by Goh, Lee, and Nyam (2022) and Wang, et al., (2022) to study the consumers' knowledge on plant-based meat products.

There were fifteen questions divided into three sections. The first section required sociodemographic information such as gender, course, education level, religion, and dietary habit. The second section assessed their general knowledge about PBM, including the main ingredients, food processing, environmental benefits, and types of PBM products in the market. The last section evaluated the knowledge about specific PBM nutrition profile, including calorie, carbohydrates, dietary fibre, fat, protein, polyphenols, and antioxidants content in PBM items. For Section 2 and 3, the questions were answered by choosing either "Yes", "No", or "Not sure".

3.9.6 Statistical Analyses

The results were expressed in frequency and percentage (%). Bloom's cut-off category was applied to assess the consumers' knowledge level on PBM items, in which "Yes" was scored as one ("1") and "No" and "Not sure" were scored as zero ("0"). Based on the total score, the knowledge level was categorised as low, moderate, or high (Alzahrani, et al., 2022).

CHAPTER 4

RESULTS

4.1 Proximate Analyses

Table 4.1 illustrates the proximate analysis result for the plant-based meat (PBM) samples. Among the samples, variations in ash content were statistically different ($p < 0.05$). The Avocado Charcoal Bun (ACB; 0.83 ± 0.01) exhibited the highest ash content, followed by Caviar Cappelli D'Angelo with Truffles (CDT; 0.60 ± 0.02) and Steak de Boeuf with Truffle Sauce (SBT; 0.31 ± 0.02). Besides, moisture content also displayed significant differences among the samples, with SBT (62.70 ± 0.63) having the highest moisture content, followed by CDT (0.60 ± 0.02) and ACB (0.83 ± 0.01).

Conversely, the remaining proximate analysis components (fat, protein, crude fibre, and carbohydrates) showed no statistically differences among the samples ($p > 0.05$). Despite the absence of statistical significance, the crude fibre content in ACB (8.50 ± 3.50) and SBT (8.50 ± 1.00) exceeded that of CDT (1.00 ± 0.00). For fat, protein, and carbohydrates, the results exhibited notably similarity across the samples.

Table 4.1: Proximate analysis of sample dishes made from plant-based meat (PBM) items.

Components	ACB	CDT	SBT	p-value
Ash (%)	0.83 ± 0.01^{a}	0.60 ± 0.02^{b}	0.31 ± 0.02^{c}	<0.05
Moisture (%)	51.40 ± 0.43^{a}	61.72 ± 0.12^{b}	62.70 ± 0.63^{b}	<0.05
Fat (%)	1.89 ± 0.11^{a}	2.00 ± 0.67^{a}	3.11 ± 0.00^{a}	>0.05
Protein (%)	0.13 ± 0.04^{a}	0.11 ± 0.02^{a}	0.07 ± 0.02^{a}	>0.05
Crude fibre (%)	8.50 ± 3.50^{a}	1.00 ± 0.00^{a}	8.50 ± 1.00^{a}	>0.05
Carbohydrate (%)	37.25 ± 6.30^{a}	34.58 ± 1.66^{a}	25.31 ± 3.18^{a}	>0.05

All data are expressed in means ± SE. Means with different superscripts within the same row denote significantly different at $p < 0.05$. ACB: Avocado charcoal bun; CDT: Caviar cappelli d'angelo with truffles; SBT: Steak de boeuf w/h truffle sauce.

4.2 TPC, TFC, and TAC (DPPH and ABTS)

Table 4.2 presents the total phenolics content (TPC), total flavonoids content (TFC), and total antioxidant capacities (TAC) of PBM items are. There were significant differences ($p < 0.05$) observed among all samples in all tests, except for TFC, where the results exhibited no significant variations ($p > 0.05$). The highest phenolics content was observed in SBT while the lowest was observed in CDT. Similar outcome was mirrored in the results of TAC (DPPH and ABTS assays). When it comes to DPPH and ABTS, the antioxidant activity percentage (%) and IC_{50} results typically show opposite patterns. In simpler terms, higher antioxidant activity percentage leads to lower IC_{50} values and vice versa.

Table 4.2: Total phenolics content (TPC), total flavonoids content (TFC), and total antioxidant capacities (TAC) comprising of DPPH and ABTS for sample dishes made from PBM items.

Test Items		**ACB**	**CDT**	**SBT**
TPC (μg GAE/g)		2.64 ± 0.50^{a}	1.00 ± 0.15^{b}	3.17 ± 0.12^{a}
TFC (μg QE/g)		2.10 ± 0.40^{a}	1.02 ± 0.01^{a}	1.47 ± 0.81^{a}
TAC (DPPH)	AA%	35.38 ± 0.08^{b}	18.52 ± 0.23^{c}	70.76 ± 0.75^{a}
	IC_{50} (μg /mL)	3.17 ± 0.28^{a}	$3.17 \pm 0.62^{a,b}$	1.45 ± 0.02^{c}
TAC (ABTS)	AA%	$46.72 \pm 0.50^{a,b}$	34.38 ± 6.46^{b}	59.99 ± 6.96^{a}
	IC_{50} (μg /mL)	6.18 ± 2.04^{a}	11.01 ± 7.46^{a}	4.19 ± 0.47^{a}

All data are expressed in means ± SE. Means with different superscripts within the same row denote significantly different at $p < 0.05$. AA%: Antioxidant activity percentage (%); IC_{50}: Half-maximal inhibitory concentration. ACB: Avocado charcoal bun; CDT: Caviar cappelli d'angelo with truffles; SBT: Steak de boeuf with truffle sauce.

4.3 Pearson's Correlation Coefficient among TPC, TFC, and TAC (DPPH and ABTS)

There was a very strong positive correlation between the results of TPC and TAC, including both DPPH (r = 0.881) and ABTS (r = 0.952) in Table 4.3. Similarly, the correlation between DPPH and ABTS was strong and positive (r = 0.984). Conversely, TFC displayed a weak-to-moderate correlation with the other three analyses.

Table 4.3: Pearson's Correlation Coefficient (r) among the four antioxidant analyses (TPC, TFC, DPPH, ABTS)

Traits	TPC	TFC	DPPH
TPC	-	-	-
TFC	0.661	-	-
DPPH	0.881	0.229	-
ABTS	0.952	0.400	0.984

*Significant level at $p<0.05$

4.4 Knowledge Level of UTAR (Kampar) Students on Plant-based Meat (PBM) Items

4.4.1 Socio-demographic Profiles

According to Table 4.4, a total of 165 of respondents were recruited in this study. The questionnaire encompassed socio-demographic variables such as gender, course of study, educational level, religions, and diet patterns. Among the respondents, 72.1% were female, while 27.9% were male. The majority (66.1%) of participants were pursuing Science-related courses in UTAR (Kampar Campus). Distribution across academic years was as follows: 34.5% were from Year 1, 27.3% from Year 2, 31.5% from Year 3, and 6.7% from Year 4 and above. Religions involved included Muslims (1.8%), Christians (9.7%), Buddhists (81.8%), and others (6.7%). Additionally, a significant portion of the respondents (96.4%) identified as non-vegetarians, with only a marginal 3.6% practising a vegetarian diet.

Table 4.4: Descriptive analyses of the socio-demographic profiles of respondents (n=165).

Variables		Frequency	Percentage (%)
Gender	Female	119	72.1
	Male	46	27.9
Course	Non-science	56	33.9
	Science	109	66.1
Education level	Year 1	57	34.5
	Year 2	45	27.3
	Year 3	52	31.5
	Year 4	9	5.5
	> Year 4	2	1.2
Religion	Buddhism	135	81.8
	Christian	16	9.7
	Muslims	3	1.8
	Others	11	6.7
Diet pattern	Non-vegetarian	159	96.4
	Vegetarian	6	3.6

4.4.2 Knowledge Level on PBM Items

Table 4.5 represents the detailed responses about the survey of UTAR (Kampar Campus) students' knowledge level on PBM items. The first section, comprising four questions on general understanding about PBM items. Majority of the respondents exhibited an accurate response rate ranging from 72.1% to 81.8%.

The question with the highest positive response (i.e. yes) was regarding the main ingredient of PBM items, in which people are aware that they are made from non-meat ingredients such as soy, wheat gluten, and peas.

The subsequent section, encompassing six questions on the nutritional composition of PBM items. Responses to this section showed a broader distribution across the options: "yes," "no," and "not sure." Positive responses (i.e., "yes") varied from 43% to 70.9%. Specifically, the question related to the low-fat content had the highest rate of correct responses. Conversely, the question about the amino acid profile yielded the lowest proportion of accurate responses.

Table 4.5: Frequency distribution of UTAR students' knowledge on plant-based meat and their nutritional composition (n=165)

Variables		**Frequency**	**%**
PART I: General Knowledge about Plant-Based Meat Items			
Do you think plant-based meat consumption can bring health benefits, as well as environmental sustainability and animal welfare preservation?	Yes	119	72.1
	No	27	16.4
	Not sure	19	11.5
Do you know that plant-based meat items are primarily made from isolated plant proteins such as soy, wheat gluten and peas?	Yes	135	81.8
	No	15	9.1
	Not sure	15	9.1

Table 4.5: Frequency distribution of UTAR students' knowledge on plant-based meat and their nutritional composition (n=165) (Continued)

Variables		**Frequency**	**%**
Do you think plant-based meat items involve a high degree of processing method?	Yes	120	72.7
	No	15	9.1
	Not sure	30	18.2
Do you know that plant-based meat on the market comes in various forms, including plant-based meat dumplings, plant-based meat sausages and plant-based meatballs etc.?	Yes	126	76.4
	No	20	12.1
	Not sure	19	11.5
PART II: Knowledge about Nutritional Composition of Plant-Based Meat Items			
Does plant-based meat have lower calorie content?	Yes	84	50.9
	No	35	21.2
	Not sure	46	27.9
Does plant-based meat have higher carbohydrates?	Yes	97	58.8
	No	26	15.8
	Not sure	42	25.5
Does plant-based meat have higher dietary fibre?	Yes	104	63
	No	21	12.7
	Not sure	40	24.2
Does plant-based meat have lower fat content?	Yes	117	70.9
	No	22	13.3
	Not sure	26	15.8

Table 4.5: Frequency distribution of UTAR students' knowledge on plant-based meat and their nutritional composition (n=165) (Continued)

Variables		**Frequency**	**%**
Does plant-based meat have lower amino acid profile?	Yes	71	43
	No	31	18.8
	Not sure	63	38.2
Does plant-based meat have higher antioxidant activity and polyphenolic compounds?	Yes	76	46.1
	No	19	11.5
	Not sure	70	42.4

Based on the Bloom's cut-off category in Table 4.6, students in UTAR (Kampar) generally had low level of understanding and familiarity concerning PBM items, with 37.0% of respondents falling within this category. A moderate knowledge level was demonstrated by 26.7% of participants, while a higher knowledge level regarding PBM was evident in 36.3% of respondents (as presented in Table 7).

Table 4.6: UTAR students' knowledge level on PBM items categorised by using Blooms' cut-off point

Knowledge level	**Frequency**	**Percentage (%)**
High	60	36.30
Moderate	44	26.70
Low	61	37.0

CHAPTER 5

DISCUSSION

5.1 Proximate Analysis

5.1.1 Ash

There was a significant difference ($p < 0.05$) in the ash content among the three plant-based meat (PBM) dishes. The ash content represents the inorganic residues, primarily the minerals (and sometimes impurities) remaining, after moisture and organic matter are removed from a sample (Kamau, et al., 2020). Hence, the ash content represents mineral compositions, such as calcium, magnesium, sodium, and potassium. Processed food like PBM often reported markedly higher sodium level and salt content compared to the corresponding meat products (Ohlau, Spiller, and Risius, 2022), thereby highlighting the nutritional implications of ash content values.

Among the samples, Avocado Charcoal Bun (ACB) had the highest ash content (0.83%), closely aligning with the range (0.84-3.0%) indicated by Swing, et al. (2021) in their proximate analysis study of plant-based burgers. The variation in ash content can be explained by ingredient differences. Firstly, the burger bun in ACB was added with activated charcoal, a factor that Haghighat, Honarvar, and Mooraki (2023) stated to influence the ash content. Similar outcome was reported by Kobus-Cisowska, et al. (2019), where ash content was increased in ash-incorporated bread, equivalent to the mineral elements present in charcoal.

Besides, the high ash content in ACB could be attributed to the addition of vegetables (baby spinach, tomatoes) and fruits (avocado) that were not included in the other two dishes. According to Kamau, et al. (2020), vegetables had higher ash content compared to fruits. They reported the ash content of spinach was 1.73±0.03, avocado was 0.84±0.02, and tomato was 0.46±0.01. As seen in the ingredient list (Table 1), the primary ingredients of ACB consists of PBM items and fresh vegetables and fruits. Conversely, the remaining two dishes, CDT and SBT, lacked fresh ingredients. Particularly in SBT, the major ingredient of the dish was plant-based steak, a highly-processed meat substitute instead of fresh ingredients. Alcantara, Hurtada, and Dizon (2013) reported higher ash content found in fresh taro than processed taro products (e.g. taro noodles and taro cookies), implying mineral elements might be destructed and lost during food processing.

5.1.2 Moisture

The moisture content of our samples falls within the range reported by Swing, et al. (2021), which was between 49.7 – 69.3%. Among the samples, SBT demonstrated the highest moisture level, which was significantly different from ACB, but was non-significantly different from CDT. Despite all samples involved PBM items as their main ingredients, each dish comprised different ingredients, some of which naturally had higher water content than others. For instance, in the case of ACB, Gonzalez, et al. (2020) documented a moisture content of 40.45% in the charcoal bun, in which the dryness could be due to the nature of baked goods. Furthermore, Bakhsh, et al. (2021a) and Bakhsh, et al.

(2021b) pointed out that a higher moisture content often correlates with a high fat content, contributing to the dishes' overall juiciness. In this study, similar outcome and patterns were observed, especially evident in SBT, in which it had the highest moisture and fat content.

5.1.3 Fat

He, et al. (2020) reported the fat content of their PBM burger samples (n=6) ranged from 4.67 to 15.93g/100g. Similarly, Bryngelsson, et al. (2022) reported 4.4 to 23g/100g of fat content in PBM burger found in Swedish market. In the context of this study, the ACB had the lowest fat content (1.89%) among all samples, attributed primarily to the incorporation of fresh vegetables and fruits. Additionally, Beyond Meat burger patty was used in ACB. According to Beyond Meat's official website, their burger patty contains 14g of total fat and 5g of saturated fat per serving (113g), with no cholesterol or trans-fat. This patty also claims a 35% reduction in fat and saturated fat compared to 80/20 ground beef (Verzegnassi, 2020). This reduction in dietary fat may bring certain health benefits. Pallazola, et al. (2019) mentioned that a reduction in daily saturated fat intake from 16% to 5% effectively decreased LDL-C levels by 11% (from 131mg/dL to 117mg/dL), correlating with a decreased risk and mortality rate of stroke, coronary heart disease, and cardiovascular disease. Despite the potential advantages of processed PBM alternatives over conventional meat products, careful consideration of nutritional labels is advised to avoid items high in saturated fat and sodium (Gastaldello, et al., 2022).

On the other hand, SBT had the highest fat content (3.11%) in this study. The average fat content of normal steak (from animals) as reported by Schulte, Avena, and Gearhardt (2015) was 24g. Besides, the Beyond Meat Steak claimed to have 6g of total fat per serving (88g). Although the total fat reported on the packaging for steak (6g/serving) was lower than the burger patty (14g/serving), the total fat content in SBT was recorded higher than ACB. The high fat content shaped the distinct sensory attributes with increased juiciness, tenderness, and flavour in SBT. Besides, the result variations could be due to the diverse food ingredients in each sample. For example, ACB included more fresh fruits and vegetables such as baby spinach and tomatoes that are low in fat content. Meanwhile, SBT included high-fat fried foods like French fries as a side dish. As a reference, the McDonald's French fries contain 14.1g of fat per serving, while Burger King Regular French fries have 11.6g of fat per serving (70g) (Stastny, Keith, and Hall, 2014).

5.1.4 Protein

In this study, the samples yielded relatively uniform protein content, ranging between 0.07 to 0.13%, with the highest value observed in ACB. The protein content of PBM mainly relies on the plant-based protein sources. For instance, ACB incorporated pea proteins in the Beyond Meat burger patty, offering 35 - 40% of high-quality protein. Similarly, SBT employed Beyond Meat Steak, enriched with fava bean-rich flour, containing up to 64% of protein (Vlassopoulos and Kapsokefalou, 2023; Webb, Li, and Alavi, 2022). However, other studies reported a broader range of protein content in PBM burgers, with values from 9.33 to 17.70g/100g as reported by He, et al. (2020), and 16.07 – 16.96/100g as reported by Bakhsh, et al. (2021a). Comparatively, our findings appeared lower than the ranges documented in previous studies, likely due to the fact that PBM was merely a component of the dishes. As referred to the ingredient list (Table 1), our dishes contained additional ingredients that could influence the overall protein content. Mayer Labba, et al. (2022) additionally mentioned that protein content can also be affected by different protein sources, extraction, and extrusion methods.

More than half (~60%) of the PBM products in the market claimed they are "rich in protein" on their packaging (Curtain and Grafenauer, 2019). However. various studies have indicated that PBM products tend to possess lower protein content compared to their animal-meat counterparts. For instance, Swing, et al. (2021) demonstrated such conclusion from their study on five PBM products in comparison with 80/20 ground pork and 80/20 ground beef. Protein content of ground beef ranked highest (26.0g/100g), followed by PBM products from Beyond Meat (23.8g/100g) and ground pork (21.5g/100g). Besides the low protein content, most plant-based proteins (except soy protein) often consist of incomplete amino acid profiles. For example, legumes are low in amino acid methionine. As a result, nutritional deficiencies remain a concern in plant-based diets (Hughes, et al., 2014; Mayer Labba, et al., 2022). Nevertheless, recent study conducted by Rudloff, et al. (2019) concluded that the total protein intake among vegan and vegetarian children and adolescents did not significantly differ from those following omnivorous diets. Craig, et al. (2021) emphasized that the protein needs of vegetarian or vegan youth are typically met through diverse dietary choices. As recommended in the RNI (Recommended Nutrient Intakes for Malaysia) published by Ministry of Health Malaysia (MOH, 2005), the concept of complementary protein is encouraged, in which the combination of two or more incomplete protein can fulfil the needs for all essential amino acids. Common pairings include grains and legumes (Woolf, Fu, and Basu, 2011).

5.1.5 Dietary Fibre

According to Bakhsh, et al. (2021a), their PBM samples contained around 4 – 5% of fibre. In this study, the results closely aligned with those reported in previous studies. Although there was no significant difference among the samples, ACB and SBT showed the highest fibre content at 8.50% while CDT was 1.00%. The higher fibre content in ACB could be attributed to the inclusions of other fresh ingredients such as avocado, tomato, and baby spinach. In contrast, CDT contained a larger proportion of angel hair pasta, a wheat-based variety known for its carbohydrate abundance (74-77%) but relative deficient in dietary fibre (Panghal, et al., 2019).

When compared to animal meat, PBM are generally reported higher dietary fibre. A study by Bakhsh, et al. (2021b) reported PBM analogues containing 6.87% of fibre while pork and beef contained 2.63% and 1.56% respectively. He, et al. (2020) indicated that PBM burgers featured higher fibre, ranging from 1.77 – 5.31g/100g while beef burger had 0.00 – 0.88g/100g. These findings suggest that PBM can be considered a healthier option compared to red meats due to their increased dietary fibre content. Mullins and Arjmandi (2021) mentioned that diets high in fibre have demonstrated improvements in postprandial glycemic response and glycated haemoglobin (HbA1C) among Type 2 Diabetes Mellitus patients. In addition, Jenkins, et al. (2012) highlighted that low-GI, high-fibre legume diet with a minimum of 190g (1 cup) of legumes daily significantly improved HbA1C, total cholesterol, triglycerides, blood pressure, heart rate, body weight, and waist circumference.

5.1.6 Carbohydrates

PBM products generally exhibit higher carbohydrate content compared to animal meat or meat substitutes. A study conducted in Swedan by Bryngelsson, et al. (2022) showed that the median carbohydrate content for PBM samples (ranging from 1.0% to 6.0%) was higher compared to meat references (ranging from 0.0% to 5.0%). This high carbohydrate content is primarily due to the presence of plant-based ingredients such as wheat gluten, pea protein, soy, and other legumes (Curtain and Grafenauer, 2019). For instance, wheat gluten is reported to comprise nearly 75% starch, while pea has 50-70% carbohydrates, and soybeans contribute around 30% of carbohydrates (mainly in the form of non-starch polysaccharides) (Apper-Bossard, 2013; Webb, Li, and Alavi, 2022).

Previously, He, et al. (2020) documented a range of carbohydrate content between 2.65% to 18.67% in their PBM samples. Our study revealed even higher carbohydrates content levels, ranging from 25.31% to 37.25%, when compared to previous findings. The difference can be attributed to the inclusion of other ingredients that could contribute to the overall carbohydrate content. For example, the burger bun in ACB and angel's hair pasta in CDT. Meanwhile, it is noteworthy that the carbohydrate by difference (CBD) method, employed in this study, is highly reliant on the accuracies of determinations of other components (i.e. ash, moisture, fat, protein, crude fibre). Cumulative errors from these previous analyses could potentially influence the carbohydrate results (Myers and Croll, 1921). Despite being mandated by the US regulations for nutrition labelling, the CBD method might not adequately represent the precise total carbohydrate in the food samples. For enhanced accuracy, it is recommended to directly measure the carbohydrate content using techniques like chromatographic and electrophoretic methods, chemical assays (phenol-sulfuric and anthrone), enzymatic methods (D-glucose, D-fructose, maltose, sucrose), physical methods (polarimetry, refractive index), or immuneassays (Hewitt, 1958; BeMiller, 2017; Shankaramurthy and Somannavar 2019).

5.2 TPC, TFC, and TAC (DPPH and ABTS assays)

5.2.1 Total Phenolics Content (TPC)

Generally, PBM products tend to have higher total phenolic content (TPC) compared to their conventional meat counterparts. Abdullah, et al. (2022) showed that the TPC of PBM was notably higher than their conventional meat type. For example, the plant-based steak had a TPC of 1.33 ± 0.04, which was significantly higher than that of the conventional steak, which was 0.87 ± 0.03. The incorporation of plant proteins into these products may contribute to increased levels of bioactive compounds, resulting in higher TPC content.

Phenolic compounds have been reported to be responsible for the antioxidant activity of food. Usually, high amount of phenolic compounds is associated with high antioxidant activity (Othman, et al., 2014). In this study, SBT showed the highest TPC (3.17±0.12), which demonstrated similar patterns with the results of its antioxidant activity (AA%) assessed through DPPH (70.76±0.75) and ABTS (59.99±6.96) scavenging assays. A strong correlation ($r = 0.881$, follows $0.7 < r < 0.89$) was observed between the result of TPC and DPPH, while a very strong correlation (0.952, follows $0.90 < r < 1.00$) was observed between TPC and ABTS. The correlation indicated that the antioxidant activity was significantly associated with the phenolic content in PBM samples. In other words, the higher the phenolic content, the higher the antioxidant activity. Goh, Lee, and Nyam (2022) reported the same observations in the correlations between TPC, DPPH, and ABTS. Besides, TPC of SBT was 20% higher than ACB and 317% higher than CDT. This difference could be explained by the variations in the protein ingredients used in the plant-based meats. The Beyond Meat Steak in SBT was formulated with fava bean protein. A study on plant-based protein flour conducted by Millar, et al. (2019) reported the highest TPC in fava bean flour (387.52mg GAE/100g).

Furthermore, the presence of additional ingredients, such as herbs and spices, could contribute to the variations in TPC among the PBM samples. In SBT, oregano and bay leaves were included during cooking aimed to enhance flavour and aroma. Previous research, like Muchuweti (2007), indicated that oregano had the highest TPC (15.83mg GAE/100g), while bay leaves were ranked in the middle with a moderate-to-high TPC (12.5mg GAE/100g). Another study conducted by Ali, et al. (2021) supported this finding, showing oregano with the highest TPC (140.56 mg GAE/g) and bay leaves with a moderate TPC (33.93mg GAE/g).

Although phenolic compounds are known for their antioxidant benefits. Certain components within total phenols might bring nutritional limitations to the food. As highlighted by Millar, et al. (2019), a higher TPC in fava bean flour could potentially lead to decreased protein bioavailability. This is due to the antinutritional properties of total phenols, such as tannins and phenolic acids, which can bind to proteins and minerals within the food matrix. This binding reduce their accessibility for digestion and absorption. Mayer, et al. (2022), stated that high phytate content (a type of total phenols) in plant proteins (e.g. soy, pea, and wheat protein) might result in reduced iron and zinc bioavailability in meat analogues. This highlights the potential association between plant-based diets and nutritional deficiencies, in which often involve inadequacy of protein and essential micronutrients such as iron and zinc in vegans and vegetarians.

5.2.2. Total Flavonoids Content (TFC)

Earlier research has consistently showed an elevated total flavonoids content (TFC) in plant-based food samples. For example, Wang, et al. (2022) reported a significant TFC in fava beans, reaching as high as 6.9mg catechin equivalent/g compared to peas with a much lower level of less than 0.2mg catechin equivalent/g. However, this study showed different results. The TFC across our PBM samples exhibited similarity, ranging from 1.00 to 2.6 μg QE/g, with ACB showing the highest TPC, followed by SBT and CDT. These TFC results did not demonstrated statistically significant differences among the samples ($p > 0.05$).

Moreover, the Pearson's correlation coefficient analysis revealed weak-to-moderate correlation ($0.10 < r < 0.69$) between TFC and the other three assays (TPC, DPPH, and ABTS). This suggests that while phenolic compounds appear to directly contribute to antioxidant activities, it does not conclusively establish an association between flavonoids content and antioxidant activities in our PBM samples. Figure 1 illustrates that flavonoids are a subgroup of phenolic compounds. The high correlation between TPC but low correlation with TFC in relation to the DPPH and ABTS suggests that flavonoids might not be the predominant contributors to the phenolic compounds in our PBM samples. Other phenolic compounds such as tannins, coumarins, lignans, quinones, stilbenes, curcuminoids, or other such compounds could potentially play a more significant role.

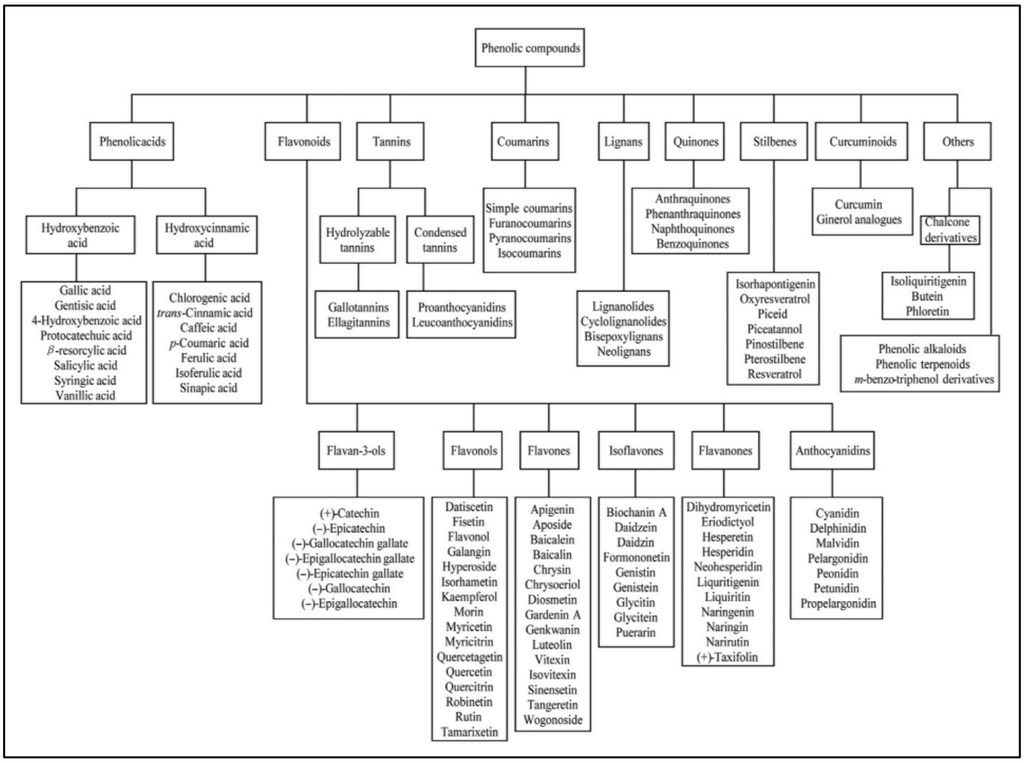

Figure 5.1: Subgroups of the phenolic compounds (Gan, et al., 2019).

5.2.3 Total Antioxidant Activity (TAC) Through DPPH And ABTS Assays

The antioxidant activity was estimated using DPPH and ABTS scavenging assays. In the DPPH assay, SBT had the highest antioxidant activity (AA%) (70.76±0.75), followed by ACB (35.38±0.08) and CDT (18.52±0.23). A similar trend was observed in the ABTS assay, with SBT displaying the highest value (59.99±6.96), followed by ACB (46.72±0.50) and CDT (34.38±6.46). Although both DPPH and ABTS determine AA%, the ABTS values were higher than those obtained from the DPPH assay for PBM samples (except SBT). Capanoglu, et al. (2018) observed similar result, where the AA% in ABTS was recorded to be higher than in DPPH. Xing, et al. (2022) explained that the soluble nature of ABTS reagent in both aqueous and organic solvents allows it to evaluate the antioxidant capacities of extracts in both hydrophilic and lipophilic environments. Unlike DPPH, which is soluble only in organic solvent and captures hydrophobic components.

In addition, the IC_{50} serves as an indicator of antioxidant efficacy, indicating the concentration required to reduce the initial radical concentration by 50%. A lower IC_{50} denotes higher antioxidant activity, signifying that fewer antioxidants are needed to neutralize the radicals (Rivero-Cruz, et al., 2020). Importantly, IC_{50} values and AA% exhibit an inverse relationship, in which higher the AA% corresponds to lower the IC_{50}. In this study, the IC_{50} for DPPH and ABTS assays followed a similar pattern, with SBT displaying the highest IC_{50}, followed by ACB and CDT.

The elevated DPPH and ABTS activities in SBT was primarily due to the inclusions of fava bean ingredients and the incorporation of herbs and spices. Millar, et al. (2019) compared the DPPH activity of different flours (wheat, peas, and fava bean flours), finding that fava beans had the highest DPPH (250.81 mg AAE/100g) among the flours tested. Besides, the herbs added in the SBT, primarily oregano and bay leaves, further contributed to its antioxidant potency. Muchuweti, et al. (2007) reported that the DPPH activity in bay leave was the highest (91.1%), while oregano was 89.8%.

5.3 Consumers' Knowledge on Plant-Based Meat Items

The questionnaire results revealed that undergraduate students from UTAR (Kampar, Malaysia) have better grasp of general knowledge concerning PBM items, compared to their understanding of specific nutritional composition. Majority of the participants demonstrates a significant level of awareness about the key ingredients of PBM (81.8%) and the types of PBM products in the market (76.4%). The survey findings indicated that 72.1% of the respondents perceived consuming PBM as beneficial for health, environmental sustainability, and animal welfare. This perspective aligns with the findings observed by Mohamed, et al. (2017), which highlighted health, environmental, and animal as important factors influencing the adoption of plant-based diets in the Chinese community in Malaysia.

Furthermore, in the study of Mohamed, et al. (2017), 54% of non-vegetarian respondents in Malaysia self-reported that they have knowledge about vegetarian food and diets. Similar to their study, most of our respondents are also non-vegetarian, however, our results showed varying knowledge level among the undergraduate students from UTAR (Kampar) concerning questions specifically related to nutritional composition of PBM. Majority (50.9%) believed that PBM has a lower calorie content, higher carbohydrate content (58.8%) and dietary fibre content (63%). While only 43% are aware that PBM has a lower amino acid profile and 46.1% believe it has higher antioxidant activity. These results displayed a low accuracy rate was observed compared to the responses in previous section (Part 1: General Knowledge about PBM Items).

Based on the Bloom's cut-off point, the majority of respondents fall under the "low" knowledge level (37.0%), indicating the lack of understanding in PBM products and a necessity for knowledge enhancement. Varela, et al. (2022) discovered similar issue as their respondents from France expressed their lack of knowledge and self-confidence about plant-based foods.

The findings highlighted the need for educational efforts to increase awareness and comprehensive of various aspects of PBM, notably emphasizing the interpretation of nutritional claims and labels. Despite PBM is often claimed for its health benefits, Curtain and Grafenauer (2019) raised the concerns about a potential "health halo" effect surrounding PBM products. These products are frequently perceived as a healthful choice, but on a closer look, there may have some limitation in the formulations of products (e.g. high sodium content). Therefore, the practice of reading nutritional labels enables consumers to comprehend the nutritional composition and processing methods of food products. This empowers consumers to make informed food choices beyond the stereotypes associated with specific food groups. The world's largest fast food restaurant chain, McDonald's, committed to its Balanced Lifestyle Initiatives, where they proactively educate their customers on nutrition. Visible improvements were observed, such as customers are now able to notice nutrition information posters at counters after the education (Samsudin, et al., 2011). Another example comes from Malaysia, where the Instagram-based education platform, Info-Nutriteen ®, showed positive acceptances (92.7%) among adolescents and effectively improved their attitude and practice on nutrition label (Jefrydin, et al., 2020).

5.4 Significance of Study

The key finding of this study is the nutritional composition of different PBM dishes, highlighting their differences and similarities in proximate analysis, total phenolics content, total flavonoids content, and total antioxidant capacities. Besides, the study provides insights on the health implications of consuming PBM. In comparison to previous research on conventional meat products, dishes made with PBM items are relatively lower in fat and higher in dietary fibre, indicating a healthier diet option. Moreover, the correlation between phenolic compounds and antioxidant activity suggests that these PBM dishes could offer antioxidant benefits as aligned with previous studies. This aspect is significant in understanding the potential health effects of PBM beyond basic macronutrient composition. Also, the descriptive analysis of the consumer knowledge of PBM items revealed gaps in knowledge regarding specific nutritional compositions of PBM. This emphasizes the importance of educational initiatives to improve consumers' understanding of PBM and their nutritional benefits.

5.5 Limitations of Study

The limited number of PBM samples is one of the limitations of this study. There were only three PBM dishes (n=3) included as the study's samples, which might not adequately reflect the broader nutritional composition of PBM dishes in general. Besides, samples lacked standardisation. The nutritional composition varied widely based on different brands, ingredients, seasoning, and cooking methods applied in the preparation of the PBM sample dishes. Although the study acknowledges the impact of ingredient differences on nutritional content, this variability could introduce confounding factors. Furthermore, some methods might not adequately capture the actual nutritional values. For example, as mentioned earlier, the carbohydrate by difference (CBD) method for carbohydrate determination highly depends on the accuracies of other components. Combined errors from prior analyses might impact the accuracy and precision of carbohydrate estimation. On the other hand, the Kjeldahl method measures total nitrogen content without distinguishing between protein-bound nitrogen and non-protein nitrogen (e.g. free amino acid and ammonia compounds) (Muñoz-Huerta, et al., 2013). Subsequently, it could lead to an overestimation of protein content in the samples. This potential limitation is supported by Hayes (2020), who mentioned that Kjeldahl method was found to overestimate the protein content in different foods by 40-71%.

In terms of assessing consumers' knowledge about PBM items, the sample size was limited to a specific group of respondents, which was the Malaysian undergraduate students from UTAR (Kampar, Malaysia). The sample size (n = 165) was inadequate to be representative of the broader population, which could impact the generalizability of the results. Besides, most respondents were from Science-related course. The findings might not be applicable to other demographic groups with different levels of education and awareness.

5.6 Recommendations for Future Studies

For future research on the nutritional aspects of PBM items, it is recommended to include a more extensive collection of PBM samples and increase the sample size. In addition, future studies may consider the effect of different cooking method on the nutrients. Perhaps a standardisation on cooking method is necessary. Moreover, it is crucial to consider the influence of storage temperature on sample quality. Nutrient concentrations, especially those of antioxidant components (e.g. phenolic compounds), have the potential to change over time, thus impacting measurements of total phenolics and antioxidant capacities. To maintain the quality of the samples, it is advisable to store them at a constant freezing temperature (-20°C) until further analysis. Care should be taken to avoid extended defrosting periods that unnecessarily exposed the samples under room temperature, potentially leading to nutrient degradation. Furthermore, specific mineral tests (e.g. sodium, potassium, calcium, iron) may be considered as processed food like PBM may contain significant amount of sodium level. For enhanced accuracy in analysis, exploration of diverse analytical methods is important. This could involve the incorporation of advanced techniques such as high-performance liquid chromatography (HPLC) or liquid chromatography-mass spectrometry (LC-MS) to effectively identify and quantify phenolic compounds. By integrating these advanced methods, the reliability of the results can be significantly improved.

Turning to future investigations concerning consumer knowledge of PBM items, it is recommended to expand the study's participant pool to represent a wider range of demographics. This might include various age groups, educational levels, and cultural backgrounds, thereby enhancing the generalizability of the results. Additionally, The study may extend to different culture and countries to evaluate how consumers' knowledge vary across different regions. To reach out more participants from diverse backgrounds, it may be insufficient to rely solely on online surveys in English. As an alternative, questionnaires could be translated into languages such as Chinese and Tamil to accommodate populations with limited literacy in English. Distributing hard copies of the questionnaire could also facilitate wider distribution and participation.

CHAPTER 6

CONCLUSION

In conclusion, this study determined the nutritional composition of plant-based meat (PBM) products with the carbohydrate accounted the majority of macronutrient proportions. Besides, our samples exhibited high-fibre, low-fat, yet low-protein content. The PBM samples showed remarkable amount of phenolics and flavonoids content. In particular, the phenolics content is highly correlated to the antioxidant capacities as observed in both DPPH and ABTS free radical scavenging assays. Different from previous studies, our study evaluated the entire cooked dish (including other ingredients), rather than focusing on the raw PBM item itself. In this way, the result was able to provide a comprehensive idea about the actual nutrient values of a plant-based dishes on the table, instead of an estimation of nutritional value on raw items. As in reality. the proclaimed nutritional value on food packaging may not represent the final nutritional value when the food is served. Hence, this study may break the "health halo" effect in which people believed all plant-based food products are healthy without considering other factors influencing the nutrients (e.g. cooking method, storage time, and interaction with other ingredients). Besides, this study also revealed low knowledge level among Malaysian undergraduate students in UTAR (Kampar), indicating a lack of understanding and awareness of PBM items as a novel food choice. Thus, these findings also emphasize the need for targeted educational efforts to bridge the gap between general awareness and specific nutritional knowledge among consumers, ensuring well-informed dietary choices. Despite limitations such as sample size and demographic specificity, the study's outcomes contribute valuable insights to the discourse on plant-based diets, nutrition, and consumer education.

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APPENDICES

Appendix A

FM-IAD-005

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FACULTY OF SCIENCE

Full Name(s) of Candidate(s)	Elisa Bong Tsyr Yin
ID Number(s)	20ADB04785
Programme / Course	Bachelor of Science (Hons) Dietetics
Title of Final Year Project	Nutritional Compositions, Total Phenolics, Antioxidant Capacities, and Students' Knowledge Level About Plant-Based Meat Items

Similarity	**Supervisor's Comments (Compulsory if parameters of originality exceeds the limits approved by UTAR)**
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Signature of Supervisor	Signature of Co-Supervisor
Name: DR. CHANG SUI KIAT	Name: Ee Kah Yaw
Date: 13/9/2023.	Date: 13 / 9 / 2023

Appendix B

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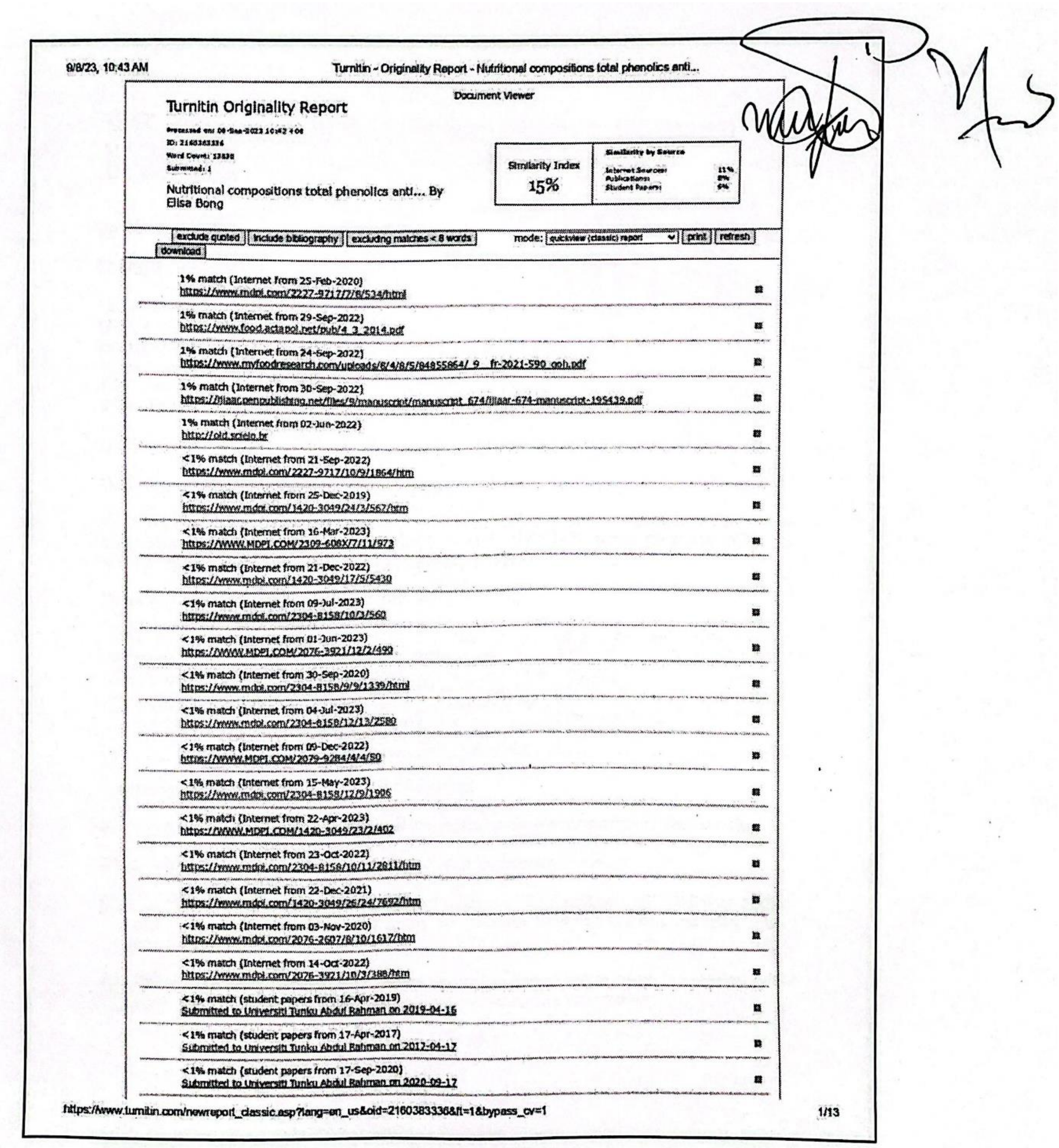

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Appendix C

Ethical Approval Letter for Research Project / Protocol

UNIVERSITI TUNKU ABDUL RAHMAN DU012(A)
Wholly owned by UTAR Education Foundation Co. No. 578227-M

Re: U/SERC/62/2023

20 March 2023

Dr Teh Lai Kuan
Head, Department of Allied Health Sciences
Faculty of Science
Universiti Tunku Abdul Rahman
Jalan Universiti, Bandar Baru Barat
31900 Kampar, Perak.

Dear Dr Teh,

Ethical Approval For Research Project/Protocol

We refer to the application for ethical approval for your students' research projects from Bachelor of Science (Honours) Dietetics programme enrolled in course UDDN3108. We are pleased to inform you that the application has been approved under Expedited Review.

The details of the research projects are as follows:

No	Research Title	Student's Name	Supervisor's Name	Approval Validity
1.	Nutritional Compositions, Total Phenolics, and Antioxidant Capacities of Plant-Based Meat Items	1. Chen Yu Wei 2. Elisa Bong Tsyr Yin 3. Oo Xing Joe	Dr Chang Sui Kiat Dr Ee Kah Yaw	20 March 2023 – 19 March 2024
2.	Microbiological Analyses and Undergraduate Student's Attitude and Perceptions About Microbiological Risk of Plant-based Meat Items	1. Careen Chong Kai Lyn 2. Siew Fei Kie 3. Wong Siew Ching	Dr Chang Sui Kiat Dr Lam Ming Quan	

The conduct of this research is subject to the following:

(1) The participants' informed consent be obtained prior to the commencement of the research;

(2) Confidentiality of participants' personal data must be maintained; and

(3) Compliance with procedures set out in related policies of UTAR such as the UTAR Research Ethics and Code of Conduct, Code of Practice for Research Involving Humans and other related policies/guidelines.

(4) Written consent be obtained from the institution(s)/company(ies) in which the physical or/and online survey will be carried out, prior to the commencement of the research.

Kampar Campus : Jalan Universiti, Bandar Barat, 31900 Kampar, Perak Darul Ridzuan, Malaysia
Tel: (605) 468 8888 Fax: (605) 466 1313
Sungai Long Campus : Jalan Sungai Long, Bandar Sungai Long, Cheras, 43000 Kajang, Selangor Darul Ehsan, Malaysia
Tel: (603) 9086 0288 Fax: (603) 9019 8868
Website: www.utar.edu.my

Should the students collect personal data of participants in their studies, please have the participants sign the attached Personal Data Protection Statement for records.

Thank you.

Yours sincerely,

Professor Ts Dr Faidz bin Abd Rahman
Chairman
UTAR Scientific and Ethical Review Committee

c.c Dean, Faculty of Science
Director, Institute of Postgraduate Studies and Research

Kampar Campus : Jalan Universiti, Bandar Barat, 31900 Kampar, Perak Darul Ridzuan, Malaysia
Tel: (605) 468 8888 Fax: (605) 466 1313
Sungai Long Campus : Jalan Sungai Long, Bandar Sungai Long, Cheras, 43000 Kajang, Selangor Darul Ehsan, Malaysia
Tel: (603) 9086 0288 Fax: (603) 9019 8868
Website: www.utar.edu.my

Appendix D

Questionnaire for the Assessment of Knowledge Level about Plant-Based Meat Items among UTAR Students

Consumer's Knowledge on Plant-Based Meat Items

Dear everyone,

We are Chen Yu Wei, Elisa Bong Tsyr Yin and Oo Xing Joe, Year 3 Students from Bachelor of Science (Hons) Dietetics in Universiti Tunku Abdul Rahman (UTAR) Kampar campus.

We are currently conducting our Final Year Project (FYP) entitled **"Nutritional Compositions, Total Phenolics, and Antioxidant Capacities of Plant-based Meat Items"**.

The **purpose of this study** is to investigate the nutritional compositions, total phenolics, and antioxidant capacities of PBM items in relation to consumer knowledge on PBM items.

To participate in this survey, you are required to fulfill the following criteria:

1. Malaysian
2. Age 18 to 30
3. Undergraduate Students in UTAR, Kampar

This questionnaire consists of **2 sections**:
Section A : Sociodemographic profiles
Section B : Consumer's knowledge on plant-based meat (PBM) items

The estimated time needed to complete this questionnaire is **5 to 10 minutes.** Your participation is greatly appreciated and you are welcome to share this message with your friends who are eligible. Thank you!

PERSONAL DATA PROTECTION NOTICE
Please be informed that in accordance with Personal Data Protection Act 2010 ("PDPA") which came into force on 15 November 2013, Universiti Tunku Abdul Rahman ("UTAR") is hereby bound to make notice and require consent in relation to collection, recording, storage, usage and retention of personal information.

1. Personal data refers to any information which may directly or indirectly identify a person which could include sensitive personal data and expression of opinion. Among others it includes:
a) Name
b) Identity card
c) Place of Birth
d) Address
e) Education History
f) Employment History
g) Medical History
h) Blood type
i) Race
j) Religion
k) Photo
l) Personal Information and Associated Research Data

2. The purposes for which your personal data may be used are inclusive but not limited to:

a) For assessment of any application to UTAR
b) For processing any benefits and services
c) For communication purposes
d) For advertorial and news
e) For general administration and record purposes
f) For enhancing the value of education
g) For educational and related purposes consequential to UTAR
h) For replying any responds to complaints and enquiries
i) For the purpose of our corporate governance
j) For the purposes of conducting research/ collaboration

3. Your personal data may be transferred and/or disclosed to third party and/or UTAR collaborative partners including but not limited to the respective and appointed outsourcing agents for purpose of fulfilling our obligations to you in respect of the purposes and all such other purposes that are related to the purposes and also in providing integrated services, maintaining and storing records. Your data may be shared when required by laws and when disclosure is necessary to comply with applicable laws.

4. Any personal information retained by UTAR shall be destroyed and/or deleted in accordance with our retention policy applicable for us in the event such information is no longer required.

5. UTAR is committed in ensuring the confidentiality, protection, security and accuracy of your personal information made available to us and it has been our ongoing strict policy to ensure that your personal information is accurate, complete, not misleading and updated. UTAR would also ensure that your personal data shall not be used for political and commercial purposes.

Consent:

6. By submitting or providing your personal data to UTAR, you had consented and agreed for your personal data to be used in accordance to the terms and conditions in the Notice and our relevant policy.

7. If you do not consent or subsequently withdraw your consent to the processing and disclosure of your personal data, UTAR will not be able to fulfill our obligations or to contact you or to assist you in respect of the purposes and/or for any other purposes related to the purpose.

8. You may access and update your personal data by writing to us at
chenyuwei2001@1utar.my (Yu Wei)
bong.elisa99@1utar.my (Elisa)
xingjoe0803@1utar.my (Xing Joe)

bong.elisa99@1utar.my Switch account

* Indicates required question

Email *

☐ Record bong.elisa99@1utar.my as the email to be included with my response

Acknowledgment of Notice *

○ I have been notified and that I hereby understood, consented and agreed per UTAR above notice.

○ I disagree, my personal data will not be processed.

Consumer's Knowledge on Plant-Based Meat Items

bong.elisa99@1utar.my Switch account

Your email will be recorded when you submit this form

* Indicates required question

Section A: Sociodemographic profiles

This section consists of 5 questions.
Please fill in your answer to each question accordingly.

Gender *

- Male
- Female

Course *

- Science
- Non-science

Education level *

- Year 1
- Year 2
- Year 3
- Year 4
- > Year 4

Religion *

- Christian
- Buddhism
- Muslims
- Others

Diet pattern *

- Vegetarian
- Non-vegetarian

Back Next Clear form

Consumer's Knowledge on Plant-Based Meat Items

bong.elisa99@1utar.my Switch account

Your email will be recorded when you submit this form

* Indicates required question

Section B: Consumer's Knowledge on Plant-Based Meat Items

This section will be separated into 2 parts:
Part 1 - General knowledge of PBM items
Part 2 - Knowledge on nutritional composition and antioxidant properties of PBM items in comparison to animal-based meat

Part 1: General knowledge of plant-based meat (PBM) items

This section consists of 4 questions.
Please read each of the question carefully.

Please choose "Not sure" if you do not know the answer.

Based on your opinion, please select the answer (Yes/ No/ Not sure) for the following questions: *

	Yes	No	Not sure
Do you think plant-based meat consumption can bring health benefits, as well as environmental sustainability and animal welfare preservation?	○	○	○
Do you know that plant-based meat items are primarily made from isolated plant proteins such as soy, wheat gluten and peas?	○	○	○
Do you think plant-based meat items involve a high degree of processing method?	○	○	○
Do you know that plant-based meat on the market comes in various forms, including plant-based meat dumplings, plant-based meat sausages and plant-based meatballs etc.?	○	○	○

Part 2: Knowledge on nutritional composition and antioxidant properties of PBM items in comparison to animal-based meat

This section consists of 6 questions.
Please read each of the question carefully.

Please choose "Not sure" if you do not know the answer.

In comparison to animal-based meat, *

	Yes	No	Not sure
Does plant-based meat have lower calorie content?	○	○	○
Does plant-based meat have higher carbohydrates?	○	○	○
Does plant-based meat have higher dietary fiber?	○	○	○
Does plant-based meat have lower fat content?	○	○	○
Does plant-based meat have lower amino acid profile?	○	○	○
Does plant-based meat have higher antioxidant activity and polyphenolic compounds?	○	○	○

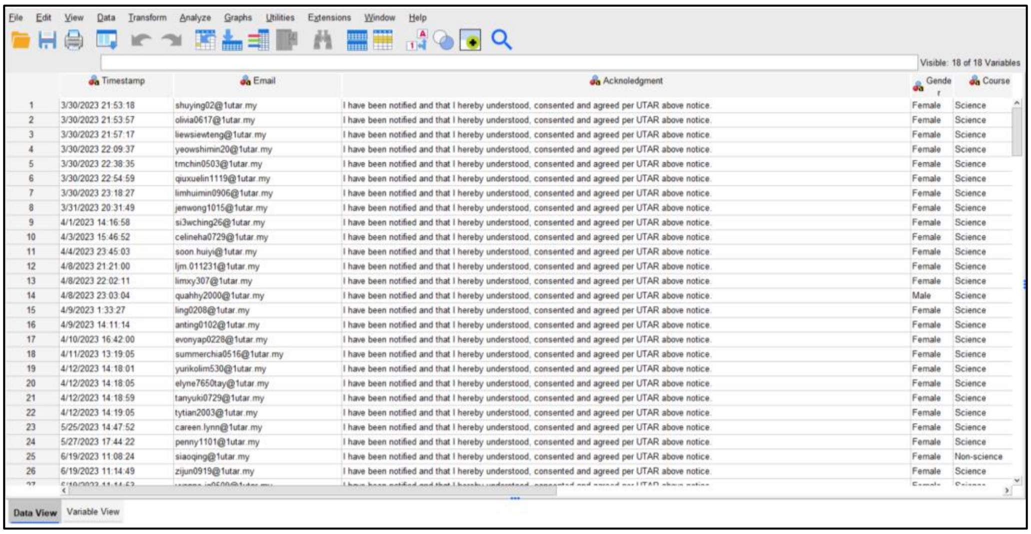
This is the end of the questionnaire!

Wishing all of you to get 4.0 in your future examination!

Stay safe and stay health!

Appendix E

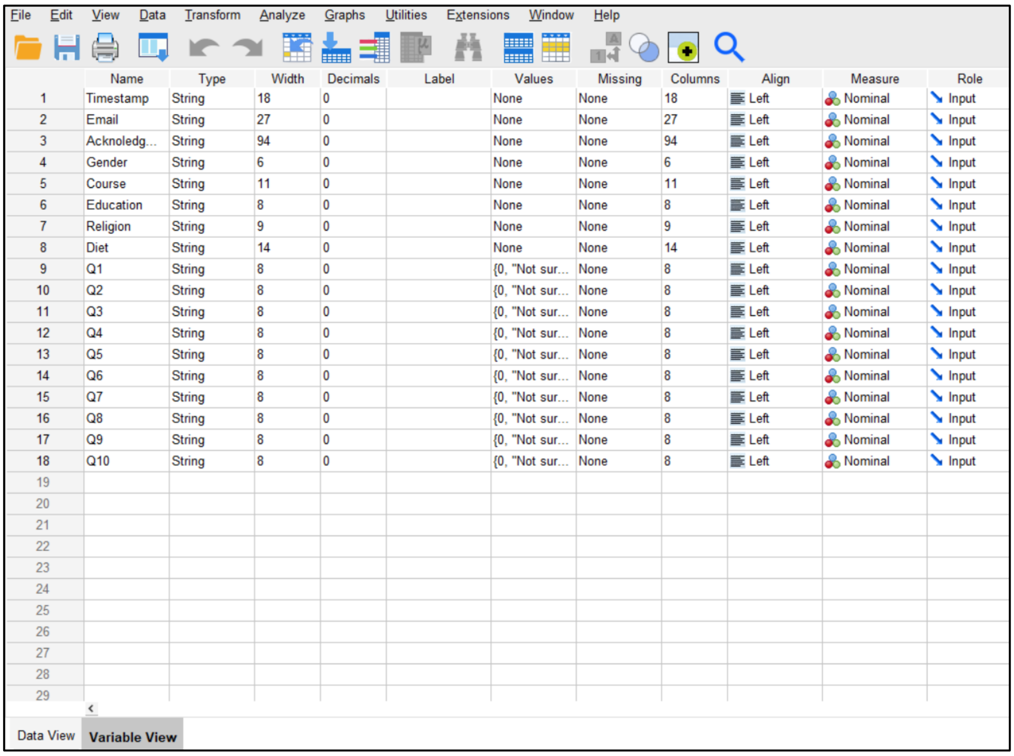
Dry Lab: Data View in SPSS Statistical Software Version 27



	Timestamp	Email	Acknoledgment	Gender	Course
1	3/30/2023 21:53:18	shuying02@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
2	3/30/2023 21:53:57	olivia0617@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
3	3/30/2023 21:57:17	liewsiewteng@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
4	3/30/2023 22:09:37	yeowshimin20@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
5	3/30/2023 22:38:35	tmchin0503@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
6	3/30/2023 22:54:59	qiuxuelin1119@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
7	3/30/2023 23:18:27	limhuimin0906@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
8	3/31/2023 20:31:49	jenwong1015@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
9	4/1/2023 14:16:58	si3wching26@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
10	4/3/2023 15:46:52	celineha0729@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
11	4/4/2023 23:45:03	soon.huiyi@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
12	4/8/2023 21:21:00	ljm.011231@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
13	4/8/2023 22:02:11	limxy307@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
14	4/8/2023 23:03:04	quahhy2000@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Male	Science
15	4/9/2023 1:33:27	ling0208@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
16	4/9/2023 14:11:14	anting0102@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
17	4/10/2023 16:42:00	evonyap0228@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
18	4/11/2023 13:19:05	summerchia0516@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
19	4/12/2023 14:18:01	yurikolim530@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
20	4/12/2023 14:18:05	elyne7650tay@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
21	4/12/2023 14:18:59	tanyuki0729@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
22	4/12/2023 14:19:05	tytian2003@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
23	5/25/2023 14:47:52	careen.lynn@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
24	5/27/2023 17:44:22	penny1101@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science
25	6/19/2023 11:08:24	siaoqing@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Non-science
26	6/19/2023 11:14:49	zijun0919@1utar.my	I have been notified and that I hereby understood, consented and agreed per UTAR above notice.	Female	Science

Appendix F

Dry Lab: Variable View in SPSS Statistical Software Version 27



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1	Timestamp	String	18	0		None	None	18	Left	Nominal	Input
2	Email	String	27	0		None	None	27	Left	Nominal	Input
3	Acknoledg...	String	94	0		None	None	94	Left	Nominal	Input
4	Gender	String	6	0		None	None	6	Left	Nominal	Input
5	Course	String	11	0		None	None	11	Left	Nominal	Input
6	Education	String	8	0		None	None	8	Left	Nominal	Input
7	Religion	String	9	0		None	None	9	Left	Nominal	Input
8	Diet	String	14	0		None	None	14	Left	Nominal	Input
9	Q1	String	8	0		{0, "Not sur...	None	8	Left	Nominal	Input
10	Q2	String	8	0		{0, "Not sur...	None	8	Left	Nominal	Input
11	Q3	String	8	0		{0, "Not sur...	None	8	Left	Nominal	Input
12	Q4	String	8	0		{0, "Not sur...	None	8	Left	Nominal	Input
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17	Q9	String	8	0		{0, "Not sur...	None	8	Left	Nominal	Input
18	Q10	String	8	0		{0, "Not sur...	None	8	Left	Nominal	Input
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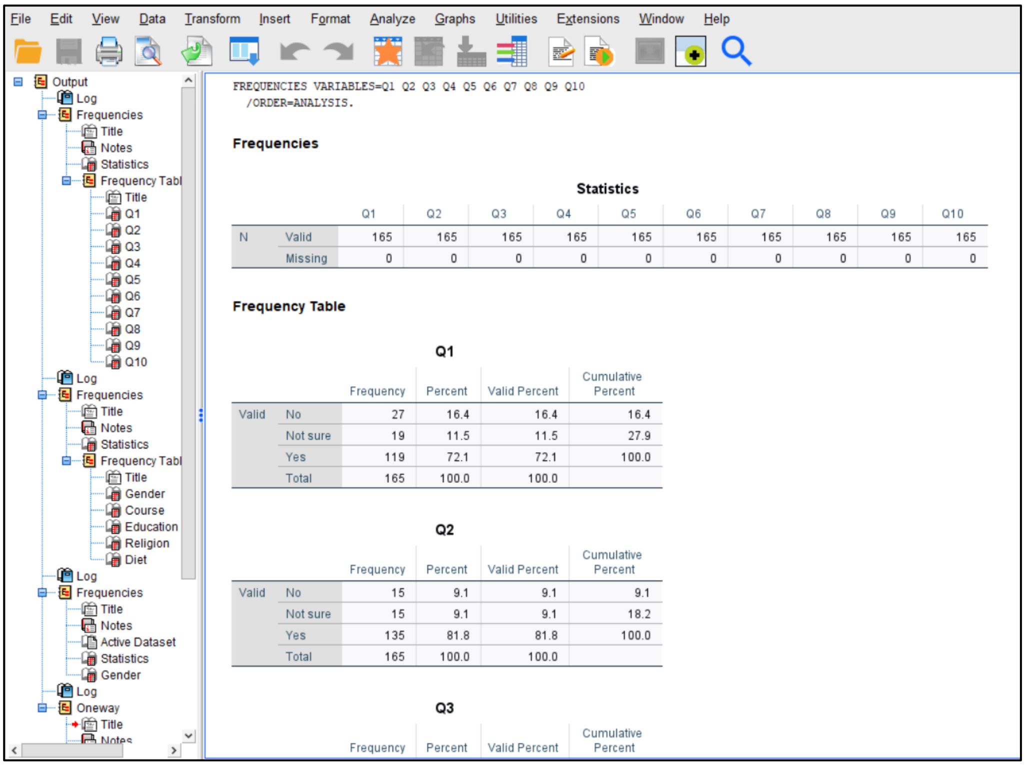
Appendix G

Dry Lab: Output View in SPSS Statistical Software Version 27



		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
N	Valid	165	165	165	165	165	165	165	165	165	165
	Missing	0	0	0	0	0	0	0	0	0	0

Q1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	27	16.4	16.4	16.4
	Not sure	19	11.5	11.5	27.9
	Yes	119	72.1	72.1	100.0
	Total	165	100.0	100.0	

Q2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	15	9.1	9.1	9.1
	Not sure	15	9.1	9.1	18.2
	Yes	135	81.8	81.8	100.0
	Total	165	100.0	100.0	