# NUTRITIONAL COMPOSITION AND PHYSICOCHEMICAL PROPERTIES OF HAZELNUT PANNED DARK CHOCOLATE WITH DIFFERENT COCOA PERCENTAGES

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**ABSTRACT –** *Cocoa consists of cocoa liquor and cocoa butter, which are essential ingredients in the production of dark chocolate. Hazelnut panned dark chocolate (HPDC) is a healthy confectionery product due to its higher cocoa content and antioxidant compounds (flavonoids and polyphenols) compared to panned milk and white chocolate products. This study was performed to determine the nutritional composition (ash, protein, fat, crude fibre, carbohydrates and energy value) and physicochemical properties (colour, texture, water activity, and pH) of HPDC with different levels of cocoa, which are 60% (HPDC-60), 70% (HPDC-70), and 80% (HPDC-80). Results showed that HPDC-70 and HPDC-80 obtained higher values ($p<0.05$) in ash (2.36-2.66%), protein (9.84-10.95%), fat (43.75-46.29%), and crude fibre (16.00-19.92%) than HPDC-60. Meanwhile, HPDC-60 yielded higher values ($p<0.05$) in carbohydrates (33.06%) and energy (880.98 kcal) compared to the other HPDC samples. In terms of lightness, HPDC-80 was darker ($p<0.05$) than the other samples. However, HPDC-60 appeared more red and yellow ($p<0.05$) compared to the other chocolate samples with higher cocoa percentages (70% & 80%). The higher addition of cocoa percentages (70% and 80%) significantly increased ($p<0.05$) the texture properties (hardness and chewiness) of HPDC samples (hardness: from 526.76 to 2095.91 N and chewiness: from 0.04 to 2.78 N) compared to HPDC with the lowest cocoa percentage (60%). The incorporation of 80% cocoa in HPDC decreased significantly ($p<0.05$) the pH (6.24) and water activity (0.35) values compared to other chocolate samples (HPDC-60 and HPDC-70). Therefore, the addition of the highest cocoa percentage at 80% improves the nutritional composition but changes the physicochemical properties of hazelnut panned dark chocolate.*

***Keywords:*** Cocoa, cocoa liquor, cocoa butter, hazelnut panned dark chocolate, nutritional

## INTRODUCTION

Chocolate is one of the most widely consumed confectionery products worldwide, enjoyed by people of all ages due to its unique flavors (sweetness and bitterness) and functional properties (Tuigunov *et al.,* 2025). Milk and dark chocolates, among the various types of chocolate, differ significantly in their cocoa solids content, which comprises cocoa liquor and cocoa butter. According to the Codex Alimentarius (2022), milk chocolate shall contain not less than 25% cocoa solids, not less than 14% milk solids, and a total fat of not less than 31%. Meanwhile, dark chocolate shall contain not less than 35% total cocoa solids and not less than 18% cocoa butter. Chocolate can be categorized into three types: dark, milk, and white, based on the percentage of cocoa used. The cocoa content of commercial dark chocolate ranges from 47% (bittersweet) to 70%, 80%, or even up to 99% for very dark chocolate (Jaćimović *et al.,* 2022). The authors also stated that the commercial dark chocolate sample with the highest cocoa content (99%) exhibited the highest antioxidant activities, as measured by DPPH free radical scavenging activity, ferric reducing power (FRAP), and total antioxidant capacity (TAC), due to its higher total polyphenols and flavonoids content. Nowadays, consumers prefer dark chocolate due to its health benefits, which include being rich in antioxidants (polyphenols and flavonoids) resulting from its higher cocoa solids content and lower sugar content compared to milk chocolate.

Regarding the nutritional composition, dark chocolate (70% cocoa) contains lower values of energy, carbohydrates, sugar, and sodium, but is higher in fats compared to white, milk, and ruby chocolates (28-47% cocoa), due to its high cocoa solids (Zarić *et al.,* 2024). Another study showed that commercial Peruvian dark chocolates (70% cocoa) have higher levels of fat, ash, protein, and energy than dark chocolate with 60% cocoa (Mejía *et al.,* 2017), due to their higher content of cocoa liquor and cocoa butter. In terms of physical properties, Zarić *et al.* (2024) reported that dark chocolate (70% cocoa) had the highest value in hardness compared to the other chocolate samples (white, milk, and ruby) due to the smaller particles present in dark chocolate. Meanwhile, chocolate bars with the highest cocoa content (90%) obtained the darkest colour (hue: 27.00°) compared to other chocolate bar samples (30-76% cocoa) (Mikołajczak & Tanska, 2021). However, there is a lack of literature data on the nutritional composition and physical properties of chocolates with different cocoa percentages.

Generally, dark chocolate contains more polyphenols than milk and white chocolates, including flavonoids (catechins, anthocyanins, and proanthocyanins), as well as other bioactive compounds, methylxanthine compounds, caffeine, theobromine, vitamins, and minerals (Samanta *et al.,* 2022). In terms of a health perspective, dark chocolate may have positive impacts on human health, including against several types of cancers and brain-related disorders (Parkinson's and Alzheimer's) and functional properties (anti-diabetic, anti-inflammatory, and anti-microbial) (Samanta *et al.,* 2022). Mikołajczak and Tanska (2021) found that dark chocolate bars (40-90% cocoa) had higher total polyphenols (252.38–703.13 mg/100 g), free flavonoids (89.55-37.63 mg/100 g) and free proanthocyanidins (212.48-52.23 mg/100 g) than milk chocolate bar (30% cocoa) (total polyphenols: 139.03 mg/100 g, free flavonoids: 24.41 mg/100 g and 28.48 mg/100 g). The same authors also reported that the highest antioxidant capacity (28.79 mM TE/100 g) was found in a dark chocolate bar with the highest cocoa content (90%) compared to other chocolate bars with 30-76% cocoa (15.30-21.30 mM TE/100 g). Besides that, the high concentration of phenolics in cocoa liquor gives dark chocolate its distinct bitterness and astringency, as well as its aroma and colour (Mikołajczak & Tańska, 2021).

Nowadays, various panned chocolate products (dark, milk, and white) with centers (fruits or nuts) are commercially available due to their desirable shape, quantity, and value. Panned chocolate is characterized by its smooth coating and glossy finish, which requires precise and consistent production processes. The production of panned chocolate involves whole coating nuts (such as almonds and hazelnuts), raisins, or other ingredients with chocolate (in dark, milk, or white varieties) until the desired form is obtained. Then, the panned chocolates are glazed with shellac and gum arabic for a glossy appearance (Fisal *et al.,* 2024).

The development of palm-based milk panned chocolate was the first literature report on the processing of panned chocolate (Hassim & Kanagaratnam, 2019). Nowadays, panned dark chocolate is one of the most widely consumed confections due to its high polyphenol and antioxidant content, as well as its acceptance among consumers (Ishak *et al.,* 2025; Ishak *et al.,* 2024). However, no studies have evaluated the nutritional quality and physicochemical properties of panned dark chocolate with different cocoa percentages. Thus, this study was conducted to develop hazelnut panned dark chocolate (HPDC) with varying percentages of cocoa (60%, 70% and 80%), and their nutritional composition (ash, protein, fat, crude fibre, carbohydrates, and energy value) and physicochemical properties (colour, texture, water activity, and pH) were determined.

## MATERIALS AND METHODS

### *Materials*

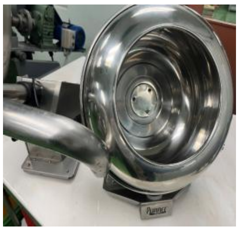
Cocoa mass (Barry Callebaut), cocoa butter (Favorich), white sugar (CSR), lecithin (Topcithin 50), and shellac (Capol® 5196) and gum arabic (Capol® 254 N) as edible glazing agents were used to produce panned dark chocolate, supplied by the Cocoa Innovation and Technology Centre, Malaysian Cocoa Board, Nilai, Negeri Sembilan, Malaysia. Meanwhile, hazelnut without skin (Yummy Bakery, Bangi, Selangor, Malaysia) was used as the centre of a panned dark chocolate. This study employed different cocoa percentages (60%, 70% and 80%) to develop three HPDC formulations as follows: HPDC-60, HPDC-70, and HPDC-80.

### *Chemicals*

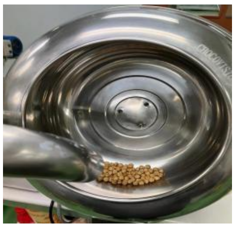
Copper catalyst tablets, sulfuric acid ($H_2SO_4$), hydrochloric acid (HCl), petroleum ether, sodium hydroxide (NaOH), anti-bumping agent, Celite 545, and methanol were used to determine the protein, fat and crude fibre of HPDC samples.

### *Development of Hazelnut Panned Dark Chocolate*

Figure 1 shows the processing of HPDC. Hazelnut was used as a chocolate centre and placed in the panning machine (Chocovision, USA) to mix with dark chocolates with different cocoa percentages (60%, 70% or 80%). Then, liquid dark chocolate (with varying cocoa percentages: 60-80%) was slowly poured over the hazelnuts in the pan. This process was completed in four hours to obtain the desirable shape, similar size, and homogeneous coating. Next, edible glazing agents (shellac and gum arabic) were applied to polish hazelnut-panned dark chocolate, enhancing its glossiness, acting as a moisture barrier, and protecting it from minor heat exposure during handling and storage. Figure 2 shows the HPDC after completing the panning process.



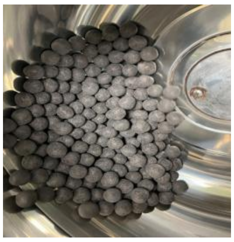
Panning machine



Hazelnut in panning machine

Liquid dark chocolate is poured over the hazelnuts in the panning machine

A 4-hour panning process is required to obtain a desirable form of hazelnut panned dark chocolate



Polishing process for hazelnut panned dark chocolate to achieve a glossy appearance

*Figure 1: Processing of hazelnut panned dark chocolate*

*Figure 2: Hazelnut panned dark chocolate*

***Nutritional Composition of Hazelnut Panned Dark Chocolate with Different Cocoa Percentages***

<u>*Moisture*</u>

The moisture of the HPDC with different cocoa percentages was measured according to the method by Melo *et al.* (2020). Moisture analysis was performed using a Thermogravimetric Moisture Determinator (LECO TGM800, USA), which had been previously calibrated. The weight of the chocolate sample loaded was ranging around 1.5±0.01 g, and the sample was taken in a temperature range from 25-700 °C. The measurements were made under a nitrogen atmosphere, and the sample was placed in an aluminium container. Thermogravimetric curves were obtained based on the temperature dependence of mass loss, and the first derivative data were calculated. The moisture content was calculated according to the formula:

$$\text{\% Moisture: } \frac{(\text{wt of wet sample + dish}) - (\text{wt of dried sample + dish})}{(\text{wt of wet sample})} \times 100$$

<u>*Ash*</u>

The ash of the HPDC with different cocoa percentages was conducted according to the method by Uzma *et al.* (2018) with modifications. The weight of the clean crucibles was recorded after drying in the desiccator. Then, 5 g of HPDC samples was added into each clean crucible and then placed in the muffle furnace (Infitek

FNC-BX1200 and China) for 6 hours at 550 °C. After that, the crucibles with ashed samples were taken out of the muffle furnace and placed in the desiccator for 1 hour (Uzma *et al.,* 2018). The crucible with ashed samples was weighed and calculated according to the formula:

Weight of ash = (wt of crucible and ash) – (wt of crucible)
% Ash = [(wt of ash) ÷ (wt of original sample)] x 100

*Protein*
The protein content of the HPDC with different cocoa percentages was determined according to the method by Halim *et al.* (2020) using the Kjeldahl procedure. About 0.7 g chocolate sample was used for the protein analysis. Protein analysis involves several methods, which are digestion, distillation, and titration (Halim, 2020). All chocolate samples were mixed with 5 g of copper catalyst tablets and 25 mL of $H_2SO_4$ in a Kjedahl flask. For the digestion step, the samples were heated from 150 °C for 30 minutes, then increased to 300 °C for 60 minutes, and then increased again to 420 °C for 5 hours. All of the processes took place in the digestion block machine with water switched on.

For the distillation process, 5L of 2% boric acid, 32% of NaOH, and deionized water were prepared. The probe was first calibrated before analyzing the samples. The digestate was neutralized by adding NaOH, which converts the ammonium sulphate to ammonia, and collected in a receiving flask containing excess boric acid, forming ammonium borate. The residual boric acid is then titrated with a standard acid, HCl, using a suitable endpoint indicator to estimate the total nitrogen content of the sample, with a conversion factor of 6.25 for nitrogen (Halim, 2020).

$$\% N = \frac{(mL\ HCl\ for\ sample - mL\ HCl\ for\ blank) \times N\ HCl \times 14.008 \times 100\%}{(Sample\ weight,\ g \times 1000)}$$

*Fat*
The fat analysis of HPDC with different cocoa percentages was conducted according to the method by Nasrabadi *et al.* (2021), using acid hydrolysis and the Soxhlet procedure. Firstly, approximately 5 g of the chocolate sample, 45 mL of hot distilled water, and 55 mL of 25 % HCl were mixed in a beaker. To avoid the development of excessive gas bubbles that might trigger over-boiling, an anti-bumping agent was added to the beaker. It was then placed under a watch glass and boiled for 15 minutes. Wet fluted filter paper was used to filter the contents, and the sample solution was rinsed three times with distilled water. The washing process was repeated until the filtrate formed a white precipitate. Wet filter paper containing the sample residues was placed into the pre-dried extraction thimble and covered with cotton wool. After that, the Soxhlet extractor was connected to the extraction thimble.

Approximately 125 mL of petroleum ether was added to the beaker connected to the Soxhlet extractor. The petroleum ether in the beaker was removed after the 4-hour procedure and left to dry for 30 minutes in a steam bath at 100 °C. After being cooled in a desiccator, dried fat samples were weighed. The total fat content of the chocolate sample can be calculated using the formula and expressed as grams per 100 grams for all the analyzed food products.

% Crude Fat = (Wt 2 – Wt 1 x 100) / Wt of sample

*Crude Fibre*
The crude fibre of the HPDC with different cocoa percentages was conducted according to the method by Ilori *et al.* (2021) with modifications. Initially, 2 g of the chocolate sample (W1) was extracted with petroleum ether and then centrifuged to remove the fat. The samples were then put into a 600 mL round-bottom flask with 200 mL of boiled 1.25% $H_2SO_4$ (0.128 M) and anti-bumping granules. The round-bottom flask containing the sample and solution was then put on the digesting equipment and boiled for 30 minutes. The sample was then filtered using vacuum suction (pre-coated with 1.5 g of Celite 545 and 75 mL of 1.25% $H_2SO_4$) and a crucible fritted glass No. 2 (200 mesh).

After that, the round-bottom flask was washed three times through the filtration apparatus with 75 mL of boiling distilled water. The residues were then placed on the digesting apparatus and heated for 30 minutes in a separate round-bottom flask containing 200 mL of boiled 1.25% NaOH (0.313 M). Previous crucible-fritted glass No. 2 (200 mesh) pre-coated with 1.5 g Celite 545 was used to filter the samples. The round bottom flask was then rinsed three times with 50 mL of distilled water and 35 mL of methanol before being rinsed with boiling 1.25% $H_2SO_4$. Vacuum suction was used to dry the residues on fritted glass, and then the samples were further dried for two hours at 130 °C. The dried residues were then weighed (W2), cooled in a desiccator, and ignited for 30 minutes at 600 °C. After that, the ashed sample was cooled in the desiccator and re-weighed (W3). The crude fibre content was calculated according to the formula:

% Crude fibre in ground test portion:

= (Loss of weight on ignition - Loss in weight of Celite blank) x 100

Weight of test portion

$$= \frac{[(W2-W30] - (B2-B3)] \times 100}{W1}$$

% Crude fibre on desired moisture basis or dry matter:
= C x (100 - % moisture desired)
(100 - % moisture in ground test sample)

*Carbohydrates*
The carbohydrate content of the HPDC with different cocoa percentages was determined according to the method by Ilori *et al.* (2021). The percentage of moisture, ash, crude protein, crude fibre, and fat was subtracted from 100 to get the amount of carbohydrates as calculation below:

[100 - (% moisture + % ash+ % crude protein + % crude fibre + % fat)]

Energy
The energy level of chocolate samples was determined according to the National Coordinating Committee on Food and Nutrition (2005) using the factors presented in Table 3.2.

Table 1: Calculation to determine the energy value

| **Nutrients** | **Amount (per 100 g)** | **Multiplied by** | **Value** |
|---|---|---|---|
| Fat | x g | 9 kcal | = kcal |
| Protein | x g | 9 kcal | = kcal |
| Carbohydrates | x g | 9 kcal | = kcal |
| Crude Fibre | x g | 9 kcal | = kcal |
| Energy content of the sample (added up) | | | = kcal |

***Physicochemical Properties of Hazelnut Panned Dark Chocolate with Different Cocoa Percentages***

*Water activity*
The water activity ($A_w$) of hazelnut panned dark chocolate with different cocoa percentages was measured in triplicate using a water activity meter (Aqualab, United States) at 22 °C. Chocolate samples were crushed by pestle and mortar before being measured for $A_w$ (Said *et al.,* 2019).

*Colour*
The colour of the chocolate samples was measured using a colorimeter (Konica Minolta CR-10 & Singapore) with a light source D, a display standard of 65, and an 8-mm beam diameter. L* (lightness), a* (redness), and b* (yellowness) on random surface areas of each sample were measured in triplicate (Nizori *et al.,* 2020). The color parameters that describe the color of HPDC with different cocoa percentages perceived by the observer were expressed using the CIELAB system: Lightness (L* = 0 black to L* = 100 white), a* (a* < 0 green to a* > 0 red) and b* (b*< 0 blue to b* > 0 yellow).

*Texture Profile*
Cylindrical probe (P75) installed on a TA.XT Plus C Texture Analyzer (Stable MicroSystems Ltd, United Kingdom) was used for penetration tests of hazelnut panned dark chocolate with different cocoa percentages. The calibration force for the penetration test (5 kg load cell and height) was carried out prior to measurement. The texture analysis was carried out at 22 °C using compression mode to penetrate the HPDC samples to a depth of 10 mm at a rate of 0.1 mm/s. The maximum penetration force through the sample was recorded for the hardness and chewiness (kg) of the HPDC samples.

*pH*
The pH of hazelnut panned dark chocolate with different cocoa percentages was measured according to the Manual of Finished Cocoa Products Analysis (Malaysian Cocoa Board, 2010). All HPDC samples were melted on a hot plate at 40 ± 2 °C until the hazelnut and chocolate became homogeneous and mixed using a stirring rod. Then, 10 g of melted HPDC samples were added to 90 mL of distilled water. The sample mixture was filtered using Whatman 4 filter paper (diameter 125 mm). The pH value of the HPDC filtrate sample was measured for three replications by a digital pH meter (HI-2211, USA).

*Statistical Analysis*
All experimental results (nutritional composition and physicochemical properties) were carried out in triplicate and expressed as mean ± standard deviation. The data was analyzed using one-way analysis of variance (ANOVA). Differences in the mean values and statistical groups were tested at a 0.05 significance level in order to determine the significance between the method variable and the final result. IBM SPSS Statistics 26 software was used for data analysis (Lapčíková *et al.,* 2022).

## RESULTS AND DISCUSSIONS

***Moisture of Hazelnut Panned Dark Chocolate with Different Cocoa Percentages***
Table 2 presents the results obtained for the moisture content of the HPDC with different cocoa percentages, ranging from 1.07% to 1.21%. No statistically significant differences were observed between the HPDC samples with varying percentages of cocoa ($p>0.05$). Similar results were reported by Velciov *et al.* (2021), who found that dark chocolate with different amounts of cocoa mass (40, 70, and 80%) had similar moisture contents (1.22-1.39%) ($p>0.05$).

Table 2: Nutritional composition of hazelnut panned dark chocolate with different cocoa percentages

| | HPDC-60 | HPDC-70 | HPDC-80 |
|---|---|---|---|
| Moisture (%) | 1.18±0.01[a] | 1.21±0.02[a] | 1.07 ±0.19[a] |
| Ash (%) | 2.09±0.04[c] | 2.36±0.01[b] | 2.66±0.11[a] |
| Protein (%) | 8.36±0.07[c] | 9.84±0.28[b] | 10.95±0.42[a] |
| Fat (%) | 41.44±0.01[c] | 43.75±0.01[b] | 46.29±0.01[a] |
| Crude Fibre (%) | 15.03±0.04[b] | 14.95±0.07[b] | 19.92±0.06[a] |
| Carbohydrate (%) | 33.06±0.03[a] | 29.07 ±0.28[b] | 20.17±0.42[c] |
| Energy (kcal) | 880.98±0.43[a] | 878.58±0.15[b] | 875.95±0.99[c] |

[a,b,c] Values with different letters in the same row are significantly different (p<0.05)
Mean±SD each value in the table is the mean of triplicate
Hazelnut panned dark chocolate (HPDC) with different levels of cocoa - 60% (HPDC-60), 70% (HPDC-70), and 80% (HPDC-80).

Chocolate with a moisture content of 0.5-1.5% does not affect the flow properties of the chocolate liquid during tempering. According to Saputro *et al.* (2019) and Beckett (2009), the moisture content of chocolate should be lower than 2% that prevent agglomeration in the chocolate structure. Moreover, a high water content (>2%) would reduce the quality of chocolate due to the formation of sugar bloom during storage (Syafira *et al.,* 2021). In this study, all HPDC samples contained moisture content lower than 2%.

***Ash of Hazelnut Panned Dark Chocolate with Different Cocoa Percentages***

HPDC-80 had the highest ash content (2.66%) ($p<0.05$), followed by HPDC-70 (2.36%) and HPDC-60 (2.09%), as shown in Table 2. The results obtained are comparable to those of a study conducted by Velciov *et al.* (2021), which found that the ash content of dark chocolate with different cocoa mass percentages (40, 70, and 80%) ranged from 1.72% to 2.24%. Furthermore, dark chocolate (70% cocoa solids) made from different cocoa hybrids in Nigeria had an ash content of between 2.24% and 2.65% (Ilori *et al.,* 2021). Ash is defined as an inorganic substance residue from the combustion of organic material. Ash content was a mixture of inorganic minerals contained in food ingredients (Sumartini *et al.,* 2022). The results showed that the highest amount of cocoa solids (80%) increased significantly ($p<0.05$) the ash content of the HPDC formulation. According to Kowalski *et al.* (2023) and Scapagnini *et al.* (2014b), magnesium, copper, potassium, and iron, which are present in dark chocolate, play a role in protein synthesis, energy production for glucose metabolism, infant growth, and brain development. Therefore, incorporation of cocoa increases the ash content of the HPDC formulation.

***Protein of Hazelnut Panned Dark Chocolate with Different Cocoa Percentages***

The protein content of HPDC with different cocoa percentages is shown in Table 2. The results showed that the addition of cocoa liquor increased significantly ($p<0.05$) the protein content of HPDC (from 8.36% to 10.95%). Overall, HPDC-80 had the highest protein content ($p<0.05$) compared to other formulations. According to Rawel *et al.* (2019), cocoa contains 11-13% protein by dry weight and may vary depending on geographical origin, ranging from 11.8% to 15.7%. Velciov *et al.* (2021) found that there was no statistically significant difference in the protein (9.82-11.32%) of dark chocolate bars with 70 and 80% cocoa solids compared to 40% dark chocolate sample (4.27%). Therefore, the protein content of HPDC can be increased significantly by incorporating cocoa solids in the formulation.

***Fat of Hazelnut Panned Dark Chocolate with Different Cocoa Percentages***

Table 2 shows the fat content of HPDC with different cocoa percentages. Results showed that incorporating cocoa solids significantly increased ($p<0.05$) the fat content of HPDC formulations. HPDC-80 reported the highest fat content (46.29%), followed by HPDC-70 (43.75%) and HPDC-60 (41.44%). A previous study by Velciov *et al.* (2021) reported that dark chocolate bars with a high amount of cocoa (70% and 80%) had higher fat contents (41.06-43.61%) ($p>0.05$) than dark chocolate bar with 40% cocoa (30.12%).

Gürsoy and Heperkan (2020) stated that all types of couverture chocolates (milk, white, and dark) are high-energy foods due to their high fat content (32-33%) and the incorporation of cocoa butter, a high-energy ingredient. Cocoa butter is rich in saturated fatty acids (95%), which consist of 34% stearic acid, 34% oleic acid, and 27% palmitic acid. Stearic acid has no significant impact on cholesterol levels. Meanwhile, oleic acid has a lowering effect on cholesterol levels. Then, cocoa butter contains 5% unsaturated fatty acids and almost no trans fatty acids (Beckett, 2008). Torres-Moreno *et al.* (2015) reported that chocolate consumption has no effects on serum total cholesterol and LDL-cholesterol. Overall, HPDC with the 80% cocoa content obtained the highest amount of fat.

***Crude Fibre of Hazelnut Panned Dark Chocolate with Different Cocoa Percentages***

The crude fibre content of HPDC with different cocoa percentages are presented in Table 3. Results showed that the addition of the highest cocoa percentage (80%) increased significantly ($p<0.05$) the crude fibre content (19.92%) of HPDC compared to other formulations (14.95-15.03%). HPDC-60 and HPDC-70 obtained similar content ($p>0.05$) of crude fibre. There are no studies to evaluate the crude fibre content of dark chocolate added with different cocoa percentages. However, previous studies by Ishak *et al.* (2023) and Rosmawati *et al.* (2022) reported that dark chocolate products had higher crude fibre content than the milk chocolate products due to the significant amount of fibre (14.1-25%) present in cocoa liquor, depending on the origin of the cocoa beans. Moreover, hazelnuts contain 11-14% dietary fibre, which is made up of insoluble fibre that can promote digestive health and may lower the risk of certain cardiovascular diseases (Di Nunzio, 2019; Dobhal *et al.,* 2018). Slavin (2013) and Kaczmarczyk *et al.* (2012) stated that high fibre intake plays a crucial role in maintaining gut health and reducing the risk of cardiovascular diseases, including obesity, diabetes, colon cancer, and heart problems. Therefore, adding the highest cocoa percentage at 80% significantly increases the crude fibre content of HPDC.

***Carbohydrates of Hazelnut Panned Dark Chocolate with Different Cocoa Percentages***

The results show that the carbohydrates in HPDC with 60%, 70%, and 80% cocoa were 33.06%, 29.07%, and 20.17%, respectively. HPDC-80 had lower carbohydrate content ($p<0.05$) than the other chocolate samples (HPDC-60 and HPDC-70). These results are good in agreement with previous study by Velciov *et al.* (2021) found that dark chocolate bar with 80% cocoa obtained the lowest content of carbohydrates (26.80%) compared to dark chocolate bars with 40% and 70% cocoa solids (35.20-59.20%) due to the high amount of cocoa mass and low sugar used in the dark chocolate formulation. Chlup *et al.* (2010) reported that 70% dark chocolate, rich in carbohydrates (50%), has a low glycemic index of 35, making it suitable for individuals with insulin resistance to aid in blood glucose regulation. Küçükyilmaz *et al.* (2024) reported that consumption of 36 g of dark chocolate (11.7 g carbohydrates) per day for 4 weeks can lower low-density lipoprotein (LDL) and total cholesterol in healthy individuals without gaining weight. Therefore, consuming HPDC with 80% cocoa offers several potential health benefits.

***Energy of Hazelnut Panned Dark Chocolate with Different Cocoa Percentages***

Energy value of HPDC with different cocoa percentages (60-80%) is presented in Table 2. Statistical analysis revealed significant differences ($p<0.05$) in energy values among all chocolate samples. HPDC-60% presented the highest energy value (880.98 kcal) ($p<0.05$) compared to other HPDC samples (875.95-878.58 kcal) due to a higher amount of carbohydrates and fats present in HPDC-60. Zugravu and Otelea (2019) suggested that the consumption of dark chocolate, while potentially beneficial for human health, should be in moderation and in an adequate portion to avoid weight gain and obesity due to its high content of fats and carbohydrates. Therefore, all HPDC with different cocoa percentages are high-calorie foods.

***Water Activity of Hazelnut Panned Dark Chocolate with Different Cocoa Percentages***

The water activity ($A_w$) of HPDC with different cocoa percentages is shown in Table 3.

Table 3: Water activity, colour, texture and pH of hazelnut panned dark chocolate with different cocoa percentages

| | HPDC-60 | HPDC-70 | HPDC-80 |
|---|---|---|---|
| Water activity ($A_w$) | 0.41±0.01$^a$ | 0.37±0.01$^b$ | 0.35±0.01$^c$ |
| L* | 38.41±0.38$^a$ | 36.59±0.54$^a$ | 33.64±0.33$^b$ |
| a* | 2.84±0.33$^a$ | 2.71±0.08$^b$ | 2.50±0.12$^b$ |
| b* | 3.97±0.31$^a$ | 2.88±0.3$^b$ | 2.8±0.38$^b$ |
| Hardness (N) | 526.76±48.40$^c$ | 1105.55±378.17$^b$ | 2095.91±123.04$^a$ |
| Chewiness (N) | 0.04±0.02$^c$ | 0.4±0.06$^b$ | 2.78±0.04$^a$ |
| pH | 6.43±0.01$^a$ | 6.36±0.04$^b$ | 6.24±0.03$^c$ |

$^{a,b,c}$ Values with different letters in the same row are significantly different ($p<0.05$)
Mean±SD each value in the table is the mean of triplicate
Hazelnut panned dark chocolate (HPDC) with different levels of cocoa - 60% (HPDC-60), 70% (HPDC-70), and 80% (HPDC-80).

Results showed that the addition of different cocoa percentages (60-80%) decreased significantly ($p<0.05$) the $A_w$ (from 0.41 to 0.35). HPDC-80 obtained the lowest $A_w$ (0.35) compared to other chocolate samples (HPDC-60 and HPDC-70) (0.37-0.41). Water activity is a crucial factor in the stability and growth of microorganisms in food products. Chocolate with $A_w$ 0.3–0.5 and moisture lower than 2% can be categorized as a low moisture food with high sugar and fat content (Sun *et al.,* 2023). Norhayati *et al.* (2013) reported that the low $A_w$ in dark chocolate makes it unsuitable for the growth of most bacteria, yeasts, and molds, which require moisture to live. However, certain spoilage microorganisms, such as *Aspergillus* sp. (fungi), can grow on the surface of dark chocolate after 2 months of storage at room temperature. Therefore, it can be expected that fungus could grow in HPDC with different cocoa percentages during storage.

***Colour of Hazelnut Panned Dark Chocolate with Different Cocoa Percentages***

Colour (L*, a* and b*) of hazelnut panned dark chocolate with different cocoa percentages are shown in Table 3. Results showed that incorporation of 80% cocoa decreased significantly ($p<0.05$) the lightness value (33.64) of HPDC compared to other chocolate samples (36.59-38.41) ($p>0.05$). It indicated that HPDC-80 was darker than the other samples due to the highest amount of cocoa liquor used in the formulation.

Wahyuni *et al.* (2021) also reported similar lightness values (30.81-31.49) for Indonesian single origin dark chocolates with 70% cocoa with the HPDC-70. Nur Fitriana *et al.* (2020) reported that cocoa liquor (22.03-27.89) from Indonesian cocoa beans were darker than the dark chocolate products with 53.8% cocoa solids (28.6-30.42). Meanwhile, HPDC-60 appeared more ($p<0.05$) red (a* 2.84) and yellow (b* 3.97) compared to other chocolate samples with higher cocoa percentages (60% & 70%). Similar findings by López-Hernández and Quintero-Cerón (2021) stated that the chocolate bar with low cocoa solids (28.77%) had higher red intensity than the chocolate bar with high cocoa contents (49.77% and 64.27%). Moreover, the chocolate colour also varied with the materials, production, tempering, storage time and temperature (Kusumawardani *et al.,* 2022). Therefore, adding 80% cocoa significantly reduces the colour properties of HPDC.

***Texture of Hazelnut Panned Dark Chocolate with Different Cocoa Percentages***

Table 3 shows the hardness and chewiness of HPDC with different cocoa percentages. Results showed that incorporating different cocoa percentages (60-80%) significantly increased ($p<0.05$) the texture properties (hardness and chewiness) of HPDC formulations. It indicated that the highest cocoa content (80%) obtained higher values of hardness (2095.91 N) and chewiness (2.78 N) compared to other formulations (hardness: 526.76-1105.55 N and chewiness: 0.4-0.04 N). Chocolate hardness or degree of "snap" is one of the important textural properties as it affects sensory evaluation and physical properties of the product (Hřivna *et al.,* 2021). Previous study by Zarić *et al.* (2024) revealed that dark chocolate with 70% cocoa solids was harder (4996 g) than other types of chocolates (ruby, white and milk) (4082-4782 g) due to smaller particles of cocoa butter and cocoa liquor present in dark chocolate which improved the specific surface area and rheological properties of chocolate. The authors also reported that a higher percentage of cocoa butter in dark chocolate significantly increased the hardness value of dark chocolate. Therefore, adding the highest cocoa content (80%) increases the texture of HPDC.

***pH of Hazelnut Panned Dark Chocolate with Different Cocoa Percentages***

pH of HPDC with different cocoa percentages are presented in Table 3. Results showed that the pH of HPDC-80 (6.24) was the lowest compared to HPDC-60 (6.43) and HPDC-70 (6.36). It can be confirmed that all hazelnut panned dark chocolate samples are slightly acidic, ranging from pH 6.24 to 6.43. Previous study by Hegde *et al.* (2009) stated that the pH of dark chocolate (6.473) was lower than that of other filled and unfilled chocolates (milk, fruit, nut and coconut) in the Indian market (6.65-6.772) due to a high level of cocoa solids in dark chocolate. According to Baleba *et al.* (2025), the pH of cocoa liquor (fully fermented dried cocoa beans) is slightly acidic (pH 5.93). De Vuyst and Weckx (2016) stated that the acidity of cocoa beans is reduced by the fermentation, drying, roasting and de-shelling, resulting in the volatilisation of acetic acid. After cocoa bean processing, chocolate conching is the subsequent step to reduce undesirable volatile acid compounds such as acetic acid, which are byproducts of cocoa bean fermentation (Engeseth & Ac Pangan, 2018). Therefore, adding cocoa mass significantly increases the pH of HPDC.

## CONCLUSIONS

The present study evaluated the effect of different cocoa percentages (60%, 70% and 80%) on the nutritional composition (moisture, ash, protein, fat, crude fibre, carbohydrates and energy) and physicochemical properties (pH, texture, colour and water activity) of hazelnut panned dark chocolate. The results concluded that the highest cocoa percentage (80%) improved the content of ash, protein, fat, and crude fibre but decreased the levels of carbohydrates and energy of hazelnut-panned dark chocolate. Furthermore, hazelnut-panned dark chocolate with 80% cocoa was darker, harder, less acidic, and had less water activity than other chocolate samples, with 70% and 60%. Therefore, incorporating a high cocoa content of 80% improved the nutritional composition and affected the physicochemical properties of hazelnut-panned dark chocolate.

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