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Effect of apple peel flour addition on physicochemical characteristics and fatty acid profile of reduced-fat mayonnaise

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ABSTRACT

Introduction: Mayonnaise is popular throughout the world and contains various types of processed products. While reduced-fat mayonnaise (RFM) contains less than 50% oil, the drawback is the potential to reduce the physical quality of mayonnaise. The use of apple peel in the form of flour added to mayonnaise is predicted to enhance its physicochemical quality. **Methods:** The research comprised laboratory experiments using randomised design with four treatments and six repetitions. Apple peel flour was added to the treatments in the following proportions: 0% (RFA0), 1% (RFA1), 2% (RFA2), and 3% (RFA3). Analysis of variance (ANOVA) was used to obtain average values and standard deviations. **Results:** Addition of 3% apple peel flour to RFM showed highly significant effect ($p \leq 0.01$) on droplet size (2.15–9.49µm), viscosity (3965.00cP), colours L (71.93), a* (15.75), and b* (50.65), protein content (1.44%), and fat content (50.93%). It also produced an organoleptic quality that was acceptable to semi-trained panellists and fatty acid profiles containing various types of fatty acids. **Conclusion:** The use of 3% apple peel flour in RFM represented the best treatment, with potential for further improvement.

Keywords: apple peel flour, reduced-fat mayonnaise, stabiliser

INTRODUCTION

Mayonnaise is popular throughout the world and encompasses several types of processed products. One very popular version is the traditional type of mayonnaise or full-fat mayonnaise (Elsebaie *et al.*, 2022). However, various low-fat mayonnaise products are currently being developed. The reduction of fat levels aligns with the trend of promoting foods with little oil content for maintaining a healthy body. The health benefits associated with such a move include reducing both the fat content and the number of calories (Kumar, 2021). Oil and water are ingredients that greatly influence the final mayonnaise product. The role of oil is as the dispersed phase and water as the dispersing phase, both contributing significantly to the stability of the product. Reducing the amount of oil used can be a first step in achieving fat reduction; however, this would result in an unstable emulsion during the emulsifying process, hence a stabiliser would be needed to unite the oil and water.

Flour is used in almost all processed foods derived from livestock products. In the food industry, special types of flour

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have a beneficial effect on products, meaning many manufacturers prefer to use flour modified from real flour. Modified wheat flour, for example, has functional uses as a food ingredient, namely as a thickener, stabiliser, binder, and emulsifier (Kumar *et al.*, 2021). In its modified form, flour maintains the texture of food, in addition to acting as a gelling agent in emulsions to provide stability and prevent the components from separating, which has a beneficial effect on the overall physical appearance and taste of the product. Researchers have widely examined the use of flour derived from seeds, leaves, tubers, fruits, and plant waste. Some of these commonly used flours include pumpkin flour (Nidhal, Evanuarini & Thohari, 2022), banana peel flour (Evanuarini & Susilo, 2020), and watermelon peel flour (Evanuarini, Amertaningtyas & Utama, 2021). This research examined the potential use and development of apple peel waste as flour.

Apple industrial waste in the form of peels comes from the cider industry, canned apples, and puree. Batu City is known as "the city of apples" due to its many apple plantations, where some of the apples produced are processed into apple chips. To date, significant volumes of apple peel generated as industrial waste have not been handled or processed. Apple peel is generally used as a ruminant feed in various farms in Batu City and Malang Regency, where it acts as a source of fibre.

Apple peels that are processed into flour can be applied to food products. They are rich in dietary fibre, flavonoids, lipids, and ash, as well as polyphenols, unsaturated galactolipids and phospholipids (Wolfe & Liu, 2003). Dietary fibre will increase water holding capacity, emulsion, gel formation (change in texture, aroma, colour), stabilise the product, and increase shelf life (Rabetafika *et al.*, 2014). Apple peel flour contains 40.7% pectin (Subagyo & Ahmad, 2010), 9.96% crude fat, and 2.80% crude protein (Romelle, Rani & Manohar, 2016). Pectin will absorb water and reduce the water content of the product. Apple peel flour has a brownish tint and will naturally absorb water and air, meaning it must be used directly within a product. The use of apple peel flour in low-fat mayonnaise is expected to produce a unique colour, an increase in viscosity, and a different fatty acid profile. Our study aimed to determine the optimum percentage of apple peel powder to be added to reduced-fat mayonnaise (RFM) to improve its quality.

MATERIALS AND METHODS

Materials

The research material comprised RFM created using canola oil, egg yolk, and vinegar, with the addition of apple peel flour. The research methods comprised laboratory experiments with a completely randomised design, with four treatments and six repetitions. Four different apple peel flour treatments were used, with different percentages of apple peel flour and code reduced fat mayonnaise with apple peel flour (RFA): RFA0 (0%), RFA1 (1%), RFA2 (2%), and RFA3 (3%). Table 1 shows the materials used in the RFM formulation.

Apple peel flour preparation

Apple peels were obtained from apple chip manufacturers in the tourist town of Batu, Malang. Production began with the cleaning of the apple peels, which were then placed in an oven at a temperature of 60°C and dried for 46 hours. Any apple peel that was too dry was discarded. The dried peels were then mashed using a dry mill and filtered using a 100-mesh sieve.

Reduced-fat mayonnaise preparation

RFM was created based on the

Table 1. Reduced-fat mayonnaise formulation

Ingredient (%)	*RFA0*	*RFA1*	*RFA2*	*RFA3*
Canola oil	70.0	50.0	50.0	50.0
Egg yolk	20.0	20.0	20.0	20.0
Apple peel flour	0.0	1.0	2.0	3.0
Vinegar	5.0	5.0	5.0	5.0
Salt	1.5	1.5	1.5	1.5
Sugar	2.5	2.5	2.5	2.5
Mustard	0.5	0.5	0.5	0.5
White pepper	0.5	0.5	0.5	0.5
Water	0.0	20.0	20.0	20.0

RFA0: without apple peel flour; RFA1: 1% apple peel flour addition; RFA2: 2% apple peel flour addition; RFA3: 3% apple peel flour addition

formulation by Evanuarini *et al.* (2016), with some modifications. A hand mixer was first used to mix optional ingredients such as white pepper, mustard, sugar, and salt for 1 minute. Egg yolk, canola oil, and vinegar were then added. Finally, apple peel flour was added to the mixed ingredients.

Statistical analysis

Research data were processed using Microsoft Excel (Microsoft Corp., Redmond, Washington, USA). Average and standard deviation values were obtained by analysis of variance (ANOVA). All statistical analyses were carried out using IBM SPSS Statistics for Windows version 20.0 (IBM Corp., Armonk, New York, USA). Duncan's multiple range test (DMRT) was used where research data yielded different results at a significant level of 1%.

RESULTS

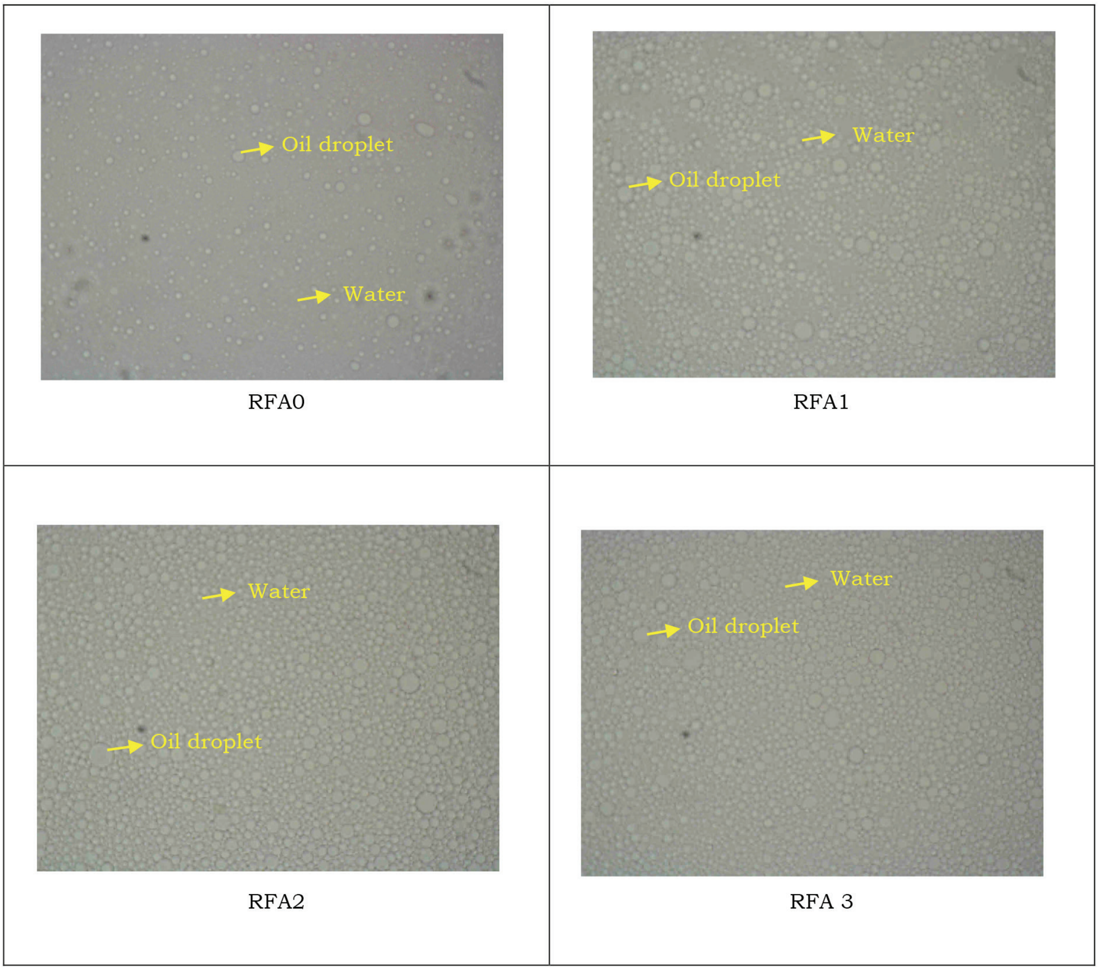
Table 2 contains the results of the emulsion droplet measurements in RFM with apple peel flour. The droplet sizes displayed for the different percentages of apple peel flour ranged from 2.15–18.15 μm. The smallest average emulsion droplet size was obtained for RFA3. The control (RFA0) mayonnaise, which received no treatment, had an emulsion droplet size of 5.32–18.15 μm. The RFM emulsion droplet results for the different percentages of apple peel flour are presented in Figure 1.

Table 2 contains the average RFM viscosity values with apple peel flour. There were signs of increased RFM viscosity with the addition of apple peel flour. The average values of RFM with apple peel flour were 3010.00–3965.00 cP. The highest viscosity was found in the mayonnaise with 3% apple peel flour (RFA3). This showed that the more apple peel flour added to the RFM, the higher the average viscosity. Based on the ANOVA results, apple peel flour had a very significant effect ($p \leq 0.01$) on the viscosity of RFM.

The average colours of L (lightness), a* (red/green), and b* (yellow/blue) in RFMs with apple peel flour are presented in Table 2. There was decreasing colour data for L in RFM with apple peel flour. The average values of the L colour in mayonnaise were 71.93–90.05, with the highest L colour found in full-fat mayonnaise (control) and the lowest in RFA3. In contrast, the colour a* in RFM with apple peel flour increased, with average colour values of 0.61–15.75. The highest a* colour was found in RFA3 and the lowest in full-fat mayonnaise. The b* colour in RFM with apple peel flour was found to decrease, with average b* colour values of 50.65–59.65. The highest b* colour was identified in control with no apple peel flour and the lowest in RFA3. ANOVA results showed that apple peel flour had a very significant effect on colours L, a*, and b* in RFM ($p \leq 0.01$).

The average protein contents of RFM with apple peel flour are presented in Table 2. The protein content in RFM increased with the addition of different percentages of apple peel flour. The average values for the protein content of mayonnaise were 1.16–1.44%. The highest protein content was found with the addition of 3% apple peel flour (RFA3) and the lowest for control mayonnaise. ANOVA results showed that apple peel flour had a very significant effect ($p \leq 0.01$) on the protein content of RFM.

Table 2 contains the average fat contents of RFM with apple peel flour. It showed that the fat content of RFM decreased with the addition of different percentages of apple peel flour. The average fat content values of mayonnaise



RFA0: without apple peel flour; RFA1: 1% apple peel flour addition; RFA2: 2% apple peel flour addition; RFA3: 3% apple peel flour addition

Figure 1. Emulsion droplets of flour in reduced-fat mayonnaise with apple peel flour at 400x magnification

Table 2. Physicochemical composition and organoleptic quality of reduced-fat mayonnaise with apple peel flour

Physicochemical	*RFA0*	*RFA1*	*RFA2*	*RFA3*
Emulsion droplets (μm)	5.32-18.15	4.48-14.76	2.99-13.02	2.15-9.49
Viscosity (cP)	3010.00±47.61[a]	3290.00±34.64[b]	3600.00±51.64[c]	3965.00±77.24[d]
L	90.05±0.62[d]	83.09±1.40[c]	74.59±1.13[b]	71.93±0.61[a]
a*	0.61±0.15[a]	7.94±0.30[b]	11.57±0.39[c]	15.75±0.64[d]
b*	59.65±0.54[d]	57.67±0.48[c]	54.74±0.68[b]	50.65±0.52[a]
Protein content (%)	1.16±0.03[d]	1.25±0.03[c]	1.33±0.02[b]	1.44±0.04[a]
Fat content (%)	68.09±0.36[d]	55.04±0.75[c]	51.48±0.42[b]	50.93±0.66[a]
Organoleptic				
Texture	3.60±0.68	3.75±0.64	4.10±0.79	4.25±0.79
Aroma	3.65±0.88	3.75±0.79	3.95±0.76	4.10±0.55
Colour	4.25±0.72	4.00±0.79	3.85±0.75	3.55±0.83
Flavour	3.75±0.72	3.95±0.76	4.00±0.73	4.20±0.77

RFA0: without apple peel flour; RFA1: 1% apple peel flour addition; RFA2: 2% apple peel flour addition; RFA3: 3% apple peel flour addition
L: lightness; a*: red/green; b*: yellow/blue
[a,b,c,d] Indicate very significant difference; $p \leq 0.01$

were 68.93–78.09%. The lowest fat content was found with the addition of 3% apple peel flour (RFA3), while the control mayonnaise had the highest fat content. The results of various analyses showed that apple peel flour had a very significant effect on the fat content of RFM ($p \leq 0.01$).

The average organoleptic values can be seen in Table 2. The organoleptic data and analysis showed no significant effect ($p \geq 0.05$) of the addition of apple peel flour on the texture, aroma, taste, and colour of RFM. In the spider graph (Figure 2), the larger the rectangle that points outward, the higher the organoleptic value. The largest rectangle shown denotes RFM with the addition of 3% apple peel flour, while the smallest is the control (RFM without treatment). Figure 2 showed that the average texture organoleptic values ranged from 3.60 to 4.25. ANOVA results showed that the addition of apple peel flour had no significant effect ($p \geq 0.05$) on the texture of RFM. The average aroma organoleptic value ranged from 3.65 to 4.10. RFA3 had the highest RFM aroma value, while control had the lowest value. As for colour, the average colour organoleptic value ranged from 3.55 to 4.25; control had the highest value, while RFA3 had the lowest value. The average taste organoleptic value ranged from 3.75 to 4.20. RFA3 had the highest score for RFM flavour, while RFA0 had the lowest.

Table 3 contains the fatty acid profile data for RFM with the addition of 3% apple peel flour (RFA3). It showed that the amount of SFA was 11.10% and the highest type of SFA was palmitic acid, as much as 7.26%. The types of SFA comprised of palmitic acid, stearic acid, arachidic acid, myristic acid, heptadecanoic acid, and heneicosanoic acid. Heneicosanoic acid had the lowest percentage among the SFA in this mayonnaise, at 0.04%. MUFA had the highest value in the types of fatty acid profile at 30.88%. MUFA comprised of unsaturated fatty acids, oleic acid, omega-9 fatty acids, eicosanoic acid, and palmitoleic acid. Palmitoleic acid had the lowest value among the different types of MUFA in this mayonnaise. Table 3 showed a value of 16.09% for

PUFA. The following types of PUFA were detected in RFM: omega-6 fatty acids, linoleic acid, omega-3 fatty acids, linolenic acid/w3, arachidonic acid, w6 acid, eicosapentaenoic acid (EPA), eicosadienoic acid, and docosahexaenoic acid (DHA).

Table 3. Fatty acid profile of reduced-fat mayonnaise with apple peel flour

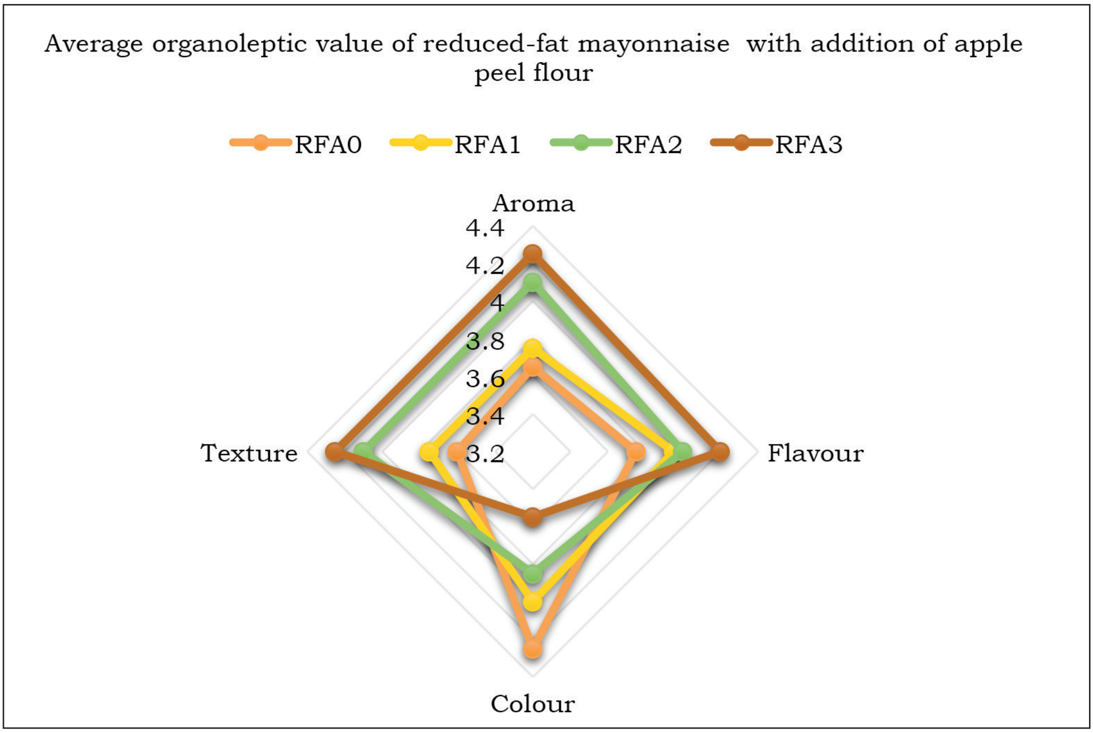
Types of fatty acids	*%*
Saturated fat	11.10
C 16:0 (Palmitic acid)	7.26
C 18:0 (Stearic acid)	3.45
C 20:0 (Arachidic acid)	0.23
C 14:0 (Myristic acid)	0.06
C 17:0 (Heptadecanoic acid)	0.04
C 21:0 (Heneikosan acid)	0.04
Monounsaturated fat	30.88
Unsaturated fats	46.97
C 18:1 W9C (c-oleic acid)	30.11
C 20:1 (Eicosanoic acid)	0.23
C 16:1 (Palmitoleic acid)	0.33
Polyunsaturated fat	16.09
Omega 6 fatty acids	12.20
C 18:2 W6 (Linoleic acid/w6)	10.87
Omega 3 fatty acids	3.80
C 18:3 (Linolenic acid/w3)	3.64
C 20:4 (Arachidonic acid)	1.01
C 18:3 (Linoleic acid/w6)	0.33
C 20:5 w3 (Eicosapentaenoic acid)	0.09
C 20:2 (Eicosadienoic acid)	0.08
C 22:6 w3 (Docosahexaenoic acid)	0.07

DISCUSSION

Figure 1 showed that during the emulsification process, a small proportion of pectin will absorb oil and some will also absorb water, thus protecting the droplets in the mayonnaise. Heating and shaking too quickly and excessively can cause the emulsion to split and form globules, which will be covered by the continuous phase (O'Brien, 2009). Oil is thus mixed slowly with the other ingredients to facilitate the tight formation of oil droplets. Conducting the dispersed and dispersing phases simultaneously will produce an emulsion in the form of water in oil, which will reduce the resulting viscosity. According to Golchoobi *et al.* (2016), a smaller particle size will change the colour of the emulsion from grey to white. Mun *et al.* (2009) revealed that creaming is prevented during the manufacture of low-fat mayonnaise products with the addition of a thickening agent, such as starch, to the aqueous phase to slow down the movement of the droplets.

The total pectin content in apple peel flour can produce an increase in viscosity. Based on the results of an introductory study, apple peel flour contains 15.35% pectin. Pectin is a type of crude fibre that can form a gel (Izzati & Salsabila, 2018). The pectin content of apple skin flour can increase the gelling of mayonnaise, thereby increasing its thickness. Pectin can also bind water or be hygroscopic, thereby reducing the water content of the product and increasing its viscosity. Amelia, Astuti & Zulferiyenni (2016) stated that gel formation can be caused by the presence of pectin; this can form fine fibres and clumps that hold liquid in the product. Furthermore, pectin is useful as a stabiliser to maintain emulsion stability and increase viscosity, thus preventing emulsion damage (Hutapea, Rusmarilin & Nurminah. 2016). Studies have shown that mayonnaise thickens with peanut powder to create a thick and stable consistency (Rudra *et al.*, 2020), while vegan mayonnaise with durian seed flour added has a viscosity value of 3160 cps (Cornelia, Siratrantri & Prawita, 2015).

Table 2 showed that the more apple peel flour added to RFM, the lower the L colour value of the mayonnaise. This is because when heated, the flour changes colour to brownish yellow, so the more apple peel flour is added, the browner the RFM. This is a positive aspect because mayonnaise will have a



RFA0: without apple peel flour; RFA1: 1% apple peel flour addition; RFA2: 2% apple peel flour addition; RFA3: 3% apple peel flour addition

Figure 2. Spider graph on the organoleptic average values of RFM with apple peel flour

different colour and can thus be used as a natural dye. Apple peel flour also contains anthocyanins, which helps in promoting skin health. The stability and effectiveness of anthocyanins render them suitable for use in products with low pH, in addition to functioning as fillers and economical natural dyes. Food colours are caused by caramelisation reactions, Maillard reactions, oxidation, and the addition of natural or artificial colouring agents (Winarno, 2004). A tendency for the colour a* to increase in RFM was observed due to the brownish colour of the apple peel flour. Rubbing it into mayonnaise produces a darker and reddish colour. The presence of hydrocolloids in mayonnaise produces a yellowish colour (Johary *et al.*, 2015). The greater the amount of apple peel flour added to RFM, the further the average b* colour value of the mayonnaise will decrease; the apple peel flour grows darker and will thus produce a bluish colour. This finding aligns with Johary *et al.* (2015), who stated that mayonnaise with added hydrocolloids would become darker and the b* value would decrease.

Protein content was mainly derived from egg yolk, which functions as an emulsifier. Apple peel flour has a protein content of only 2.36%. The greater the amount of apple peel flour added to RFM, the higher the protein content. The addition of acid, emulsifier, or other ingredients can increase the protein content of a food ingredient. Pectin is a compound that is predominantly hydrophilic since the hydrophobic part of the protein is related to arabinogalactan.

While the arabinogalactan protein structure and glycoprotein structure can increase protein levels, their contribution is limited (Hutapea *et al.*, 2016). The addition of durian seed flour to mayonnaise produced a protein content of 0.16% (Cornelia *et al.*, 2015). A combination of egg yolk and stabiliser resulted in protein levels of between 0.67 and 0.89% (Hutapea *et al.*, 2016). According to Goankar *et al.* (2010), the standard protein content of mayonnaise is 1.43%; the minimum protein content is 0.9%. The protein content of apple peel flour is 4.3 g/100g dry matter (DM).

Table 2 showed that the average fat content of mayonnaise decreased with the addition of apple peel flour. This is because vitamin C in apple peel flour affects fat oxidation, while fibre in apple peel flour binds the fat in mayonnaise. The fat content in egg yolk comprises of 65.5% triglycerides, 5.2% cholesterol, and 28.3% phospholipids. Triglycerides and phospholipids function to provide energy for daily activities, while cholesterol regulates body functions (Magistri, Yaswi & Alioes, 2016). Vegan mayonnaise containing durian seeds also has a fat content of 60.36% (Cornelia *et al.*, 2015). The fat content of RFM that combines a concentration of egg yolk and a stabiliser ranges 37.24–37.39% (Hutapea *et al.*, 2016).

Based on preliminary research, apple peel flour has a water content of around 12.71%. Its hygroscopic nature means it can also absorb more water from the ingredients contained in the product. In terms of texture, the resulting mayonnaise was very dense and thick in texture; with more apple peel flour added, the thicker the texture of the mayonnaise. Despite the distinctive aroma of apple peel flour (Falah, Kurniaty & Aprilia, 2020), when combined with mayonnaise, the latter's own distinctive aroma was slightly disguised as it was absorbed by the apple peel flour. The more apple peel flour added, the more fragrant the aroma. Apple peel flour is yellowish brown in colour (Falah *et al.*, 2020); as such, mayonnaise containing a higher level of apple peel flour was darker in colour and appeared less attractive to the panellists. In terms of flavour, apple peel flour was slightly sour and slightly lowered the pH of mayonnaise. This is due to the presence of pectin from the apple peel flour, which has a D-galacturonic acid polymer (Amelia *et al.*, 2016). Hutapea *et al.*, (2016) reported that RFM containing different concentrations of egg yolk and stabiliser yielded organoleptic texture values of between 2.01 and 4.03, organoleptic aroma values of between 4.19 and 4.01, and organoleptic taste values of between 3.01 and 3.66.

Gas chromatography was used to determine the fatty acid profile of RFM at 3% addition of apple peel flour. Fatty acids can be distinguished from the number of carbon atoms (C) by the presence of bonds and the number and location of double bonds. Fatty acids are divided based on their chemical structure to give saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA). The properties of SFA include a lack of double bonds in the hydrocarbon chain, stability, and the fact that it is neither easily oxidised nor easily turned into trans fatty acid compounds or other harmful compounds; while PUFA has characteristics such as double bonds, a liquid form at room temperature or lower temperatures, and lower melting points than MUFA and SFA. PUFA are also more susceptible to oxidation (Sartika, 2008). McClements & Decker (2000) stated that the speed of lipid oxidation is affected by the chemical structure of lipids, the presence of antioxidant and pro-oxidant compounds, the amount and type of oxygen, and the nature of the packaging material and storage temperature. The fatty acids of mayonnaise have been studied and yielded fatty acids with a composition of 27.2–39.5% PUFA, 33.2–41.7% MUFA, and 18.1–24.9% SFA (Nazari, Asgary & Sarrafzadegan, 2010). Rashed *et al.* (2017) found that palmitic acid was the dominant fatty acid in mayonnaise, by as much as 10.02 g/100 g. Oleic acid is a MUFA that can cause a bitter taste due to its binding to the hydrophobic component of the peptide.

CONCLUSION

Our research showed that apple peels-enriched mayonnaise had higher viscosity and protein content than control. Apple peel is also rich in polyphenols, mineral, and fibre, making it a potential and valuable stabiliser for reduced-fat mayonnaise production. The use of apple peel will contribute to solutions for environmental pollution. This research work concluded that the addition of apple peel flour improved the physicochemical, sensory attributes, and stability of mayonnaise.

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Authors' contributions

Herly E, created research concepts and designs, collected research data, reviewed and completed the manuscript; Agus S, conducted research, analysed data, created discussion narratives, wrote, translated and reviewed the manuscript.

Conflict of interest

We declare that there is no conflict of interest.

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