The use of tomato peel nanopowder as a natural antioxidant in low-fat mayonnaise

Herly Evanuarini[1*], *Agus* Susilo[1], and *Dedes* Amertaningtyas[1]

[1]Animal Product and Technology Department, Faculty of Animal Science, Universitas Brawijaya Malang 65145, East Java, Indonesia

Abstract. The tomato processing industry produces waste products that are not utilized and add to the problem of environmental pollution. Tomato peel still contains high bioactive components, tomatoes as the main source of beta-carotene and lycopene are expected to improve food quality. Owned antioxidant activity can reduce the oxidation process in food products. Low-fat mayonnaise is a type of low-fat mayonnaise that has a fat content of less than 40%. The purpose of this study was to investigate the effect of adding tomato peel nanopowder to low-fat mayonnaise based on emulsion stability, viscosity, moisture content, fat content, antioxidant activity, and fatty acid profile. Low-fat mayonnaise was prepared using sunflower oil, vinegar, and egg yolk by giving 1%, 2%, and 3% tomato peels nanopowder treatment, and without the addition of control which was repeated 5 times. A completely randomized design was used as the research design. Analysis of variance was used as statistical analysis and continued with Duncan's test if there were significant or very significant differences. The results of the study adding nanopowder tomato peel with different percentages had a very significant effect ($p<0.01$) on emulsion stability, viscosity, water content, fat content, antioxidant activity, and the presence of various types of fatty acids in low-fat mayonnaise. The addition of tomato peel nanopowder can increase the stability of the emulsion, viscosity, and antioxidants, as well as reduce the water content and fat content. This study concludes that 3% tomato peel nanopowder is capable of being a natural antioxidant that can improve the physicochemical quality of low-fat mayonnaise.

1 Introduction

Mayonnaise is the result of an emulsion of oil in water made by mixing egg yolks, vegetable oil, vinegar, and other optional ingredients. Mayonnaise is one of the sauces that is widely used in the food industry. Traditional mayonnaise contains as much as 70 – 80% fat, which causes concerns about excessive fat intake. The fact that occurs in society is that the amount of fat consumed is positively correlated with the number of chronic diseases such as obesity and cardiovascular disease [1]. Therefore, strategies are needed for developing food products to reduce the amount of fat but not change the taste and texture

* Corresponding author: herlyfptub@ub.ac.id

attributes. The development of low-fat mayonnaise is a challenging thing to be able to provide taste, color, and texture attributes that are almost the same as full-fat mayonnaise. If there is a reduction in fat droplets, it will affect the texture, viscosity, and stability of the emulsion in the emulsion system. Research that has previously developed includes the strategies applied, including the use of fruit and vegetable peel waste as a stabilizer in reduced-fat mayonnaise [2], [3] and the use of pumpkin as a stabilizer and source of antioxidants for reduced-fat mayonnaise [4]. This can be adopted for the development of alternative low-fat mayonnaise products.

Tomato (*Lycopersion esculentum*) is a type of fruit cultivated throughout the world. In general, tomatoes are used as a basic ingredient for making fresh sauces, tomato sauce, pasta, and processed into fresh juice as well as selling peeled tomatoes without peel. The by-products of processing fresh tomatoes are tomato peel, tomato seeds, and a mixture of peel and seeds called tomato pomace. This waste can disturb the environment due to the lack of use of by-products, considering that tomatoes have a high water content which can cause the growth of microorganisms to grow faster. Efforts to utilize tomato waste include renewable energy in biodiesel, product packaging, cereal industry, and can be used in the food industry [5–7]. Previous research stated that tomato peel contains bioactive compounds in the form of carotenoids, dietary fiber, phenols, unsaturated fatty acids, and many lycopene which can prevent non-communicable diseases in humans [8, 9]. Carotenoids are natural pigments in fruit and vegetables to produce red, yellow, and orange colors which are rich in antioxidants [10]. Carotenoids can improve the immune system and reduce the risk of degenerative diseases. Carotenoids as provitamin A bioactive compounds can increase product shelf life and sensory properties. This can streamline tomato processing and increase the added value of the product in food science. In addition, 50% of tomato peel is fiber which includes cellulose, hemicellulose, lignin, and pectin [11]. Lycopene in tomato peel as a coloring agent and antioxidant compound [6, 12, 13]. Tomato peel will be transformed into nanopowder to increase absorption and reduce particles when applied to food products. The functional properties of tomato peel are considered to be an antioxidant agent in low-fat mayonnaise.

This research investigates the effect of using tomato peel nanopowder as a natural antioxidant in low-fat mayonnaise. The parameters observed were emulsion stability, viscosity, water content, fat content, antioxidant activity, and fatty acid profile in the best treatment.

2 Materials and methods

2.1 Materials

The material used in this research was tomato peel which was separated from fresh tomatoes. Fresh tomatoes are found at the Malang City Traditional Market. The ingredients for making mayonnaise are vegetable oil, vinegar, sugar, salt, ground pepper, and mustard from local supermarkets. Meanwhile, chicken eggs are from smallholder farmers in Junrejo, Batu City.

2.2 Methods

Low-fat mayonnaise was prepared using sunflower oil, vinegar, and egg yolk by giving 1%, 2%, and 3% tomato peels nanopowder treatment, and without the addition of control which was repeated 5 times. A completely randomized design was used as the research design and are presented in Table 1.

Table 1. Experimental design and research treatment

Treatments	Descriptions
Control	Full-fat mayonnaise control with 70% oil
TP1	Low-fat mayonnaise with 30% oil and 1% tomato peels nanopowder
TP2	Low-fat mayonnaise with 30% oil and 2% tomato peels nanopowder
TP3	Low-fat mayonnaise with 30% oil and 3% tomato peels nanopowder

2.3 Preparation of Tomato Peels Nanopowder

Making tomato peel nanopowder [24] starts by separating tomato peel from fresh tomatoes. Place the tomato peels on a baking sheet lined with parchment paper. Put the tomato peels in a hot oven at 60℃ ± 2 for 6 hours. The heating process also involves turning the tomato peel every 3 hours. The dried tomato peel is refrigerated for 1 × 24 hours. The cooled dried tomato peel is put into a dry mill to be ground and filtered to 300 mesh. Furthermore, nanopowder tomato peel can be applied to low-fat mayonnaise products.

2.4 Low-fat Mayonnaise Preparation

Mayonnaise is prepared using a mixer at 2000 rpm for 10 seconds to mix sugar (2%), salt (1%), ground pepper (0.5%), and mustard (1%). After that, it is homogenized with egg yolk (20%), vinegar (5%), and vegetable oil for full fat (70%) and low fat (30%) treatment. Stirring using a mixer at 2000 rpm ± 3 minutes. The final step is to enter the tomato peel treatment with nanopowder TP1 (1%), TP2 (2%), and TP3 (3%) stirring for 30 seconds. Mayonnaise samples were put into glass jars and stored at room temperature 26℃ ± 2℃ [4].

2.5 Data analysis

All tests were carried out with five replications and produced data in the form of mean ± standard deviation. Calculation of statistical data using two-way ANOVA IBM SPSS Statistics 25.0 (IBM SPSS, Inc). Duncan's follow-up test with a level of 0.05 was carried out whether or not there was a significant difference in the data.

3 Results and Discussion

3.1 Emulsion stability

The results showed that tomato peel nanopowder had a very significant effect ($p<0.01$) on low-fat mayonnaise. The higher the percentage of added tomato peel nanopowder, the stability of the low-fat mayonnaise emulsion increases. The average of emulsion stability of low-fat mayonnaise can be seen in Table 2.

Table 2. The average emulsion stability of low-fat mayonnaise

Treatment	Emulsion Stability (%)
C	$95.00^{b} \pm 0.82$
TP1	$92.25^{a} \pm 0.96$
TP2	$93.00^{ab} \pm 0.82$
TP3	$96.00^{b} \pm 0.82$

Note: $^{a \text{ and } b}$ in the same column show a very significant effect ($p < 0.01$)

Emulsion stability is one of the important parameters in emulsion products. Emulsion instability will occur if the oil and water ratio is incorrect or the emulsifier concentration is insufficient. The emulsion stability of low-fat mayonnaise with nanopowder tomato peel is almost the same as full-fat mayonnaise. Nanopowder tomato peel can act as a stabilizer between oil and water in the mayonnaise emulsion system. Previous research stated that tomato peels contain sufficient amounts of carbohydrates to be used in food product applications [15]. Apart from that, tomato peel is a source of dietary fiber and has bioactive components that are attractive for application in the food industry as a functional food [16]. Pectin is a heterosaccharide polymer part of food fiber that has hydrocolloid properties, it can absorb water [13]. Nanopowder tomato peel can bind water and play a role in the continuous phase of the low-fat mayonnaise emulsion, thereby producing a stable emulsion. Previous research has emulsion stability of mayonnaise with watermelon rind is 87.05 – 97.79% [2].

3.2 Viscosity

The results showed that the addition of tomato peel nanopowder had a very significant effect ($p<0.01$) on low-fat mayonnaise. The higher the percentage of added tomato peel nanopowder, the viscosity of low-fat mayonnaise increases. The average of viscosity of low-fat mayonnaise can be seen in Table 3.

Table 3. The average viscosity of low-fat mayonnaise

Treatment	Viscosity (cP)
C	$3645^{c} \pm 60$
TP1	$3235^{a} \pm 93$
TP2	$3420^{b} \pm 42$
TP3	$3800^{d} \pm 62$

Notes: $^{a, b, c, \text{and } d}$ in the same column show a very significant effect ($p < 0.01$)

The increase in viscosity in low-fat tomato peel nanopowder mayonnaise is due to the pectin content in tomato peel. The viscosity in TP3 and C is almost the same, where treatment C is control with 70% oil, while low-fat mayonnaise only uses 30% oil. Pectin can replace oil and become a stabilizer so that it can increase the viscosity of low-fat mayonnaise. Previous research stated that tomato peel contains pectin which can be used as a stabilizer in food [11]. Hydrocolloids in pectin can act as a thickening agent which can reduce the fluidity of oil so that the network structure of oil in water in mayonnaise increases the viscosity of mayonnaise [17]. Other research also states that if more oil is used, it can increase the viscosity of mayonnaise [18]. Previous research about reduced-fat mayonnaise using watermelon rind flour have a viscosity around 3177.5 – 3805 cP [2].

3.3 Moisture content

The results showed that tomato peel nanopowder had a very significant effect ($p<0.01$) on low-fat mayonnaise. The higher the percentage of added tomato peel nanopowder, the lower the moisture content of the low-fat mayonnaise. The average of moisture content of low-fat mayonnaise can be seen in Table 4.

Table 4. The average moisture content of low-fat mayonnaise

Treatment	Moisture content (%)
C	$25.31^{a} \pm 0.28$
TP1	$24.52^{b} \pm 0.23$
TP2	$23.31^{c} \pm 0.47$
TP3	$22.29^{d} \pm 0.18$

Notes: $^{a, b, c, \text{and } d}$ in the same column show a very significant effect ($p < 0.01$)

The decrease in moisture content is caused by nanopowder tomato peel which plays a role in binding and absorbing water. This is caused by the complex carbohydrates in the nanopowder tomato peel interacting with water. Tomato peel has a high starch content so it can increase the adhesiveness of food products [15]. Starch has large hydroxyl groups, so it has a high water absorption capacity [19]. The absorption of water by starch granules will increase viscosity and water is trapped in the starch granules [20]. Research on reduced-fat mayonnaise with the addition watermelon rind flour have a moisture content around 15.34 – 19.28% [2].

3.4 Fat content

The results showed that the addition of tomato peel nanopowder had a very significant effect ($p<0.01$) on low-fat mayonnaise. The higher the percentage of added tomato peel nanopowder, the lower the fat content of the low-fat mayonnaise. The average of fat content of low-fat mayonnaise can be seen in Table 5.

Table 5. The average fat content of low-fat mayonnaise

Treatment	Fat content (%)
C	$70.68^{c} \pm 0.25$
TP1	$36.35^{b} \pm 0.42$
TP2	$34.90^{ab} \pm 0.62$
TP3	$34.05^{a} \pm 0.18$

Notes: $^{a, b, c}$ in the same column show a very significant effect ($p < 0.01$)

The fat content in low-fat mayonnaise with the addition of nanopowder tomato peel decreased along with the increase in treatment percentage. This is because tomato peel has a low-fat content. Reducing the fat content in low-fat mayonnaise by replacing the oil with modified additional ingredients in the form of flour [21]. Previous research also reported that the addition of ingredients rich in carbohydrates can reduce the fat content in mayonnaise [2]. Another similar research is the addition of arrowroot starches as a fat substitute in low-fat mayonnaise [18]. Low-fat mayonnaise with different stabilizer has fat contant around 49.2% [25].

3.5 Antioxidant activity

The results showed that the addition of tomato peel nanopowder had a very significant effect ($p<0.01$) on low-fat mayonnaise. The higher the percentage of added tomato peel nanopowder, the antioxidant activity of low-fat mayonnaise increases. The average of antioxidant activity of low-fat mayonnaise can be seen in Table 6.

Table 6. The average antioxidant activity of low-fat mayonnaise

Treatment	Antioxidant Activity (%)
C	$2.88^{a} \pm 0.39$
TP1	$11.09^{b} \pm 0.95$
TP2	$13.48^{c} \pm 0.33$
TP3	$16.49^{d} \pm 0.40$

Notes: $^{a, b, c, \text{and } d}$ in the same column show a very significant effect ($p < 0.01$)

The higher the addition of nanopowder tomato peel, the more antioxidant activity increases. This is caused by the presence of antioxidants and bioactive compounds in tomato peel. Tomato peel contains carotenoids as a source of coloring and also functions as an antioxidant [10]. Apart from that, tomato peel contains phenol which can be used as an antioxidant [7]. Carotenoids and phenols in tomato peel increase the antioxidant activity of low-fat mayonnaise. The peel of fruits such as tomatoes, grapes, and blueberries has strong antioxidants [22].

3.6 Fatty acid profile

The research results showed that in low-fat mayonnaise with the addition of 3% nanopowder tomato peel, there were various types of fatty acids. Types of fatty acids low-fat mayonnaise can showed in Table 7.

Table 7. Fatty acid profile of low-fat mayonnaise

Types of fatty acids	**(%)**
Myristic Acid (C 14:0)*	0.1057
Myricroleic Acid (C 14:1)*	0.0183
Pentadecanoic Acid (C 15:1)*	0.0099
Palmitic Acid (C 16:0)*	3.9962
Palmitoleic Acid (C 16:1)*	0.2500
Heptadecanoic Acid (C 17:0)*	0.0194
Heptadecanoic Acid (C 17:1)*	0.0146
Stearic Acid (C 18:0)*	1.6957
C-Linoleic Acid (C 18:2 W6C)***	17.9180
Linolenic Acid (C 18:3 W3)***	0.0088
Arachidic Acid (C 20:0)***	0.0626
Eicosenoic Acid (C 20:1)***	0.0528
Eicosadienoic Acid (C 20:2)***	0.0176
Arachidonic Acid (C 20:4 W6)***	0.2597
Oleic Acid**	10.8249
Linolenic Acid***	0.0431
Linoleic Acid***	17.9180
Omega 3 Fatty Acids	0.2915
Omega 6 Fatty Acids	18.2022
Omega 9 Fatty Acids	10.8249

Description: *Saturated Fatty Acids, **Singularly Unsaturated Fatty Acids, ***Polyunsaturated Fatty Acids

The fatty acids identified in low-fat mayonnaise with the addition of nanopowder tomato peel are mostly produced by the vegetable oil used and egg yolks. The fatty acids detected were classified into 3 types is saturated fatty acids, monounsaturated fatty acids, and polyunsaturated fatty acids. The types of fatty acids are palmitic acid, oleic acid, and linoleic acid, respectively. Palmitic acid is one of the main components that is always present in fatty acids. Essential fatty acids can function for the body and promote growth. In addition, unsaturated fatty acids can speed up the oxidation process resulting in a short product shelf life. Lipid oxidation is caused by the amount of unsaturated fatty acids which will react directly with oxygen [23]. However, the presence of tomato peel nanopowder in low-fat mayonnaise can act as an antidote to free radicals or as a natural antioxidant agent so that it can inhibit oxidative reactions.

4 Conclusion

3% nanopowder tomato peel can be a natural antioxidant in low-fat mayonnaise. The quality of low-fat mayonnaise is increased by the addition of nanopowder tomato peel.

This research was funded by the Faculty of Animal Science Universitas Brawijaya under the “Doktor Lektor Kepala” scheme with contract number 2045.2/UN10.F05/PN/2023.

References

[1] J. J. DiNicolantonio, S. C. Lucan, J. H. O'Keefe, *The Evidence for Saturated Fat and for Sugar Related to Coronary Heart Disease*, Progress in Cardiovascular Diseases, **58**, 464–472 (2016)

[2] H. Evanuarini, D. Amertaningtyas, D. T. Utama, A. R. Safitri, *The Use of Watermelon Rind Flour as Stabilizer for Reduced Fat Mayonnaise*, Jurnal Ilmu dan Teknologi Hasil Ternak, **15**, 172–182 (2020)

[3] H. Evanuarini, A. Susilo, *Optimization of Reduced Fat Mayonnaise by Using Apple Peel Flour as a Stabilizer*, Jurnal Ilmu dan Teknologi Hasil Ternak, **16**, 174–180 (2021)

[4] H. A. Nidhal, H. Evanuarini, I. Thohari, *Characteristics of reduced fat mayonnaise using pumpkin flour (Cucurbita moschata) as fat replacer*, in *E3S Web of Conferences*, EDP Sciences, (2022)

[5] S. A. Nemes, K. Szabo, D. C. Vodnar, *Applicability of agro-industrial by-products in intelligent food packaging*, Coatings, **10** (2020)

[6] G. A. Martau, M. Mihai, D. C. Vodnar, *The use of chitosan, alginate, and pectin in the biomedical and food sector-biocompatibility, bioadhesiveness, and biodegradability*, Polymers, **11** (2019)

[7] I. F. Strati, V. Oreopoulou, *Recovery of carotenoids from tomato processing by-products - A review*, Food Research International, **65**, 311–321 (2014)

[8] M. Grabowska, *Let food be your medicine: Nutraceutical properties of lycopene*, Food and Function, **10**, 3090–3102 (2019)

[9] A. C. da Silva, N. Jorge, *Bioactive compounds of the lipid fractions of agro-industrial waste*, Food Research International, **66**, 493–500 (2014)

[10] K. Szabo, *Evaluation of the Bioactive Compounds Found in Tomato Seed Oil and Tomato Peels Influenced by Industrial Heat Treatments*, (2021)

[11] F. Jiang, Y. Lo Hsieh, *Cellulose nanocrystal isolation from tomato peels and assembled nanofibers*, Carbohydr Polym, **122**, 60–68 (2015)

[12] C. Chung, G. Smith, B. Degner, D. J. McClements, *Reduced Fat Food Emulsions: Physicochemical, Sensory, and Biological Aspects*, Crit Rev Food Sci Nutr, **56**, 650–685 (2016)

[13] E. D. Ngouémazong, S. Christiaens, A. Shpigelman, A. Van Loey, M. Hendrickx, *The Emulsifying and Emulsion-Stabilizing Properties of Pectin: A Review*, Compr Rev Food Sci Food Saf, **14**, 705–718 (2015)

[14] AOAC, *Official method of Analysis*, 18th Edition. Washington DC: Method 935.14 (2005)

[15] K. Kaboré, *Effects of growing zones on nutritional and bioactive compounds of by-products of two tomato cultivars*, J Agric Food Res, **10** (2022)

[16] P. I. akubor, A. U. Owuse, *Chemical Composition, functional and biscuit making properties of tomato peel flour*, South Asian Journal of Food Technology and Environment, **06**, 874–884 (2020)

[17] W. Wang, *Physicochemical Properties, Stability and Texture of Soybean-Oil-Body-Substituted Low-Fat Mayonnaise: Effects of Thickeners and Storage Temperatures*, Foods, **11** (2022)

[18] J. J. Park, I. F. Olawuyi, W. Y. Lee, *Characteristics of low-fat mayonnaise using different modified arrowroot starches as fat replacer*, Int J Biol Macromol, **153**, 215–223 (2020)

[19] D. Donmez, L. Pinho, B. Patel, P. Desam, O. H. Campanella, *Characterization of starch–water interactions and their effects on two key functional properties: starch*

gelatinization and retrogradation, Current Opinion in Food Science, **39**, 103–109 (2021)

[20] X. Lu, R. Ma, J. Zhan, F. Wang, Y. Tian, *The role of protein and its hydrolysates in regulating the digestive properties of starch: A review*, Trends in Food Science and Technology, **125**, 54–65 (2022)

[21] A. Carcelli, G. Crisafulli, E. Carini, E. Vittadini, *Can a physically modified corn flour be used as fat replacer in a mayonnaise?*, European Food Research and Technology, **246**, 2493–2503 (2020)

[22] B. E. Ștefanescu, K. Szabo, A. Mocan, G. Crisan, *Phenolic compounds from five ericaceae species leaves and their related bioavailability and health benefits*, Molecules, **24** (2019)

[23] R. Domínguez, M. Pateiro, M. Gagaoua, F. J. Barba, W. Zhang, J. M. Lorenzo, *A comprehensive review on lipid oxidation in meat and meat products*, Antioxidants, **8** (2019)

[24] Yun, D., C. Li, Z. Wang, F. Xu, D. Chen, J. Liu, *Preparation of cost-effective and hydrophobic freshness indicating labels based on passion fruit peel powder and stearic acid*, Food Bioscience, **53** (2023)

[25] Than, W. T., S. Win, *The Effects of Various Food Stabilizers on Quality Evaluation of Low-Fat Mayonnaise*, Research Journal, **11**, 190-197 (2020)