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Research Article

Effects of Heating Method on Lycopene, Dry Matter and Nutrient Content of Tomato (*Lycopersicon esculentum*) Waste as Laying Hen Feed

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Abstract

Objective: An experiment had been conducted to evaluate the nutrient content of tomato waste for laying hen feed after treating tomato waste with different heating methods. **Materials and Methods:** The tomato waste used in this experiment was comprised of rejected fresh tomatoes from traditional markets. An experiment was performed in a 2×5 factorial arrangement using a completely randomized design (CRD) with 3 replicates. The first factor consisted of two different heating methods (steaming and boiling) and the second factor consisted of five heating durations (0, 4, 8, 12 and 16 min). The measured variables were lycopene (mg/100 g), dry matter (%), organic matter (%), ash (%) and nutrient content of tomato waste [crude protein (%) and crude fiber (%)]. **Results:** There was no interaction ($p>0.05$) between heating method and heating duration for lycopene, dry matter, crude protein, crude fiber, organic matter or ash content, while heating method significantly affected ($p<0.05$) organic matter and ash content. The heating duration also significantly affected ($p<0.05$) lycopene, dry matter, crude protein, crude fiber, organic matter and ash content of tomato waste. Boiling was better than steaming for organic matter content, while steaming was better than boiling for ash content. Crude protein and crude fiber in boiling and steaming treatments were not different. The heating duration also significantly affected ($p<0.05$) lycopene, dry matter, crude protein, crude fiber, organic matter and ash content of tomato waste. A heating duration of 12 min increased lycopene and organic matter content and maintained the crude protein content. **Conclusion:** Steaming was the appropriate method for heating tomato waste based on ash content. Heating tomato waste for 12 min was the appropriate method for increasing lycopene and organic matter content and maintaining the crude protein content.

Key words: Tomato waste, lycopene, steaming, boiling, nutrient

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Tomato (*Lycopersicon esculentum*) is a plant of the Solanaceae family from Central and South America[1]. Indonesia often produces a surplus of tomatoes. According to Srie Agustina (Director General of Domestic Trade at the Ministry of Trade of the Republic of Indonesia), Indonesia produced approximately 396,000-400,000 t of surplus tomatoes almost every year[2]. In harvesting seasons, the tomato production is abundant and the price of tomatoes is very low. Therefore, in this condition, farmers in some central areas of tomato production in Indonesia, such as Alahan Panjang in West Sumatra province, Garut in West Java province, Magetan in East Java province and Temanggung in Central Java province, often suffer a loss in production. The farmers become frustrated with the low price of tomatoes and often do not sell the tomatoes at the market due to the high cost of harvesting, instead choosing to throw them away around the farms or to leave them unpicked in the field. In this case, tomatoes become agricultural waste. Because the farmers do not process the tomatoes to be an economical product, the tomatoes became a potential product for poultry feed.

Tomatoes contain nutrients and lycopene that are needed by poultry. According to Mahata *et al.*[3], the nutrient content of tomato waste consists of 10.73% crude protein, 2.81% crude fat, 0.19% Ca, 0.28% P, 25.19% crude fiber and 1013.14 kcal kg^{-1} of metabolizable energy. Tomatoes are known to contain high carotenoid compounds in the form of lycopene[4-9]. Lycopene (also called rhodopurpurin or nonprovitamin A carotenoid) is a powerful antioxidant present in tomatoes and other vegetables and fruits[10].

Lycopene could suppress cholesterol synthesis[11,12]. Palozza *et al.*[12] reported three mechanisms involving lycopene responsible for inhibiting the cholesterol synthesis process. The first mechanism is the inhibition of 3-Hydroxy-3-methyl glutaryl coenzyme A reductase (HMG-CoA) activity in the synthesis of mevalonate. The second mechanism is the modulation of low-density lipoprotein (LDL) reductase activity, which reduces serum cholesterol concentrations by enhancing the removal of serum LDL. The third mechanism is the inhibition of acyl transferase enzyme activity in cholesterol ester synthesis, which is stored in the tissues. Previous research showed that lycopene could lower cholesterol levels in the blood serum of rabbits[13] and it could decrease the egg yolk cholesterol of quail[14]. The unsaturated nature of lycopene is also considered to be a potent antioxidant and a singlet oxygen quencher[15]. Therefore, lycopene in tomatoes is beneficial for increasing the egg quality of laying hens by lowering their egg yolk cholesterol content.

According to Bramley[16], lycopene from natural plant sources mainly exists in the trans configuration and it is also bonded to the matrix cell wall[17]. Dewanto *et al.*[18] suggested that thermal processes might break down cell walls and weaken the bonding forces between lycopene and the tissue matrix. Such disruptions in the cell wall fraction may enhance the release of lycopene from the matrix. Mahata *et al.*[3] reported the lycopene content in boiled tomatoes to be higher than that in unboiled tomatoes (62.900 vs. 57.402 ppm).

Stahl and Sies[19] stated that cis-isomers of lycopene are better absorbed in the digestive tract than the all-trans parent structure, which could be due to the greater solubility of cis-isomers in mixed micelles and a lower tendency of cis-isomers to aggregate. Tapiero *et al.*[20] and Goula *et al.*[21] stated that lycopene may undergo isomerization from trans to cis by light, heat and chemical reactions. Furthermore, Thompson *et al.*[9] reported that placing tomatoes in boiling water at a temperature of 100 °C for 8 min could increase the lycopene content for all varieties of tomato, such as agriset, solar set, FL7765 and FL7655, from concentrations of 3027, 4323, 6710 and 5712 μg/100 g to 4044, 4756, 7194 and 6613 μg/100 g, respectively. Miglio *et al.*[22] stated that different heating methods can affect the nutrient and physicochemical characteristics of some vegetables. Heating various vegetables (carrots, broccoli and courgettes) using different methods (boiling, steaming and frying) showed that antioxidants and carotenoids for all types of vegetables increased when using the boiling method but vitamin C levels in carrots were much lower when using the boiling and frying methods compared with the steaming method. In addition, it is suspected that the boiling method will dissolve other nutrients in vegetables. Saikia and Mahanta[23] studied the total concentrations of phenolics, flavonoids and antioxidants for vegetables cooked by steaming, boiling and microwaving. The steaming method resulted in the highest levels of total phenolics and flavonoids for tomatoes, followed by the microwave and boiling methods. The best cooking method for total antioxidant content was the boiling method, followed by the steaming and microwave cooking methods. A study was reported by Zeng[24] describing the loss of vitamin C in broccoli, spinach and lettuce during steaming, which was 14.3, 11.1 and 8.6%, respectively, compared to the loss of vitamin C during boiling, which was 54.6, 50.5 and 40.4%, respectively. During microwaving, the loss of vitamin C in broccoli, spinach and lettuce was 28.1, 25.5 and 21.2%, respectively.

Okibe *et al.*[25] investigated the effects of boiling, steaming and microwaving on the proximate and mineral compositions of fluted pumpkin (*Telfairia occidentalis*) leaves. The results indicated that there was a decrease in protein contents for steaming, boiling and microwaving of 18.36, 13.54 and 20.36%, respectively, while carbohydrate content decreased by 15.44, 18.35 and 2.53% for steaming, boiling and microwaving, respectively. The percentage reduction in nitrogen content after applying the three cooking methods was 1.10, 0.72 and 0.38% for steaming, boiling and microwaving, respectively. The results showed that the percentage decrease in P, K, Na, Ca, Mg and Fe levels was highest for boiling relative to the other cooking methods.

Previous research reported that tomato waste boiled in water at 100°C for 8 min had increased lycopene levels and could be used for as much as 7% of broiler diets without affecting the tomato waste performance, while also lowering cholesterol, LDL and triglyceride levels and increasing HDL levels in the blood serum of broilers[2]. The inclusion of 12% boiled tomato waste powder in laying hens' diets was the best level for lowering egg yolk total cholesterol levels and improving egg yolk color indexes[26].

There is still little information about how the processing of tomato waste by steaming or boiling for different durations increases the lycopene content availability and the dry matter and nutrient contents of tomato waste. Therefore, it is necessary to further investigate the best heating method (steaming or boiling) for processing tomato waste to increase its lycopene availability and nutrient content. The purpose of this study was to evaluate the nutrient content of tomato waste, particularly lycopene, by treating tomato waste with different heating methods (steaming and boiling).

MATERIALS AND METHODS

Tomato waste collection: The tomato type used was apple (*Lycopersicon esculentum L. pyriforme*), specifically the arthaloka variety with perfect phase coloring. They were collected from rejected tomatoes in a traditional market in Padang city, West Sumatera province, Indonesia.

Boiling of tomato waste in water: The tomato waste was weighed, allowing for as much as 500 g for each treatment of different heating method and heating duration. The water was boiled until it reached a temperature of 100°C and then, the tomato waste was put into the boiled water for 0, 4, 8, 12 or 16 min, according to the correct heating duration group. The tomato waste was then dried at a temperature of 60°C for 3 days and ground with a blender (Philips) to form a powder.

Steaming of tomato waste in water: Tomato waste was weighed, allowing for as much as 500 g for each treatment of different heating method and heating duration. The water was boiled until it reached a temperature of 100°C and then, the tomato waste was steamed in the boiled water for 0, 4, 8, 12 and 16 min, according to the correct heating duration group. The tomato waste was then dried at a temperature of 60°C for 3 days and ground with a blender (Philips) to form a powder.

Experimental design: The experiment was performed in a 2×5 factorial arrangement of treatments in a completely randomized design with 3 replicates. The first factor was different heating methods (steaming and boiling) of tomato waste and the second factor was different heating durations (0, 4, 8, 12 and 16 min) of tomato waste.

Measurement of lycopene: Lycopene was analyzed using a modification of the method introduced by Sharma and Le Maguer[27]. A total of 5 g of sample tomato powder were weighed and inserted into an Erlenmeyer lid lined with aluminum foil on the outside and protected from light. Then, 50 mL of solution (hexane: acetone: ethanol = 2: 1: 1 v / v) was added and shaken for 30 min using a magnetic stirrer and then separated into separate funnels, to which 10 mL of distilled water was added and then shaken again for 15 min. The polar and non-polar layers were separated, after which the top (non-polar) layer was grabbed and placed into a 100 mL measuring flask, to which an organic solvent was added to mark the boundaries. The total lycopene content of the non-polar (top) layer was determined using a UV-Vis spectrophotometer at a wavelength of 472 nm. Levels of the lycopene was calculated using the method of Sharma and Le Maguer[27] as follows:

$$\text{Lycopene (g/100 mL)} = \frac{\text{Abs}}{E_{1\,\text{cm}}^{1\%} \times t} \times 10 \times (\text{dilution})$$

Where:

C = Concentration (g/100 mL). Furthermore, the results were expressed as mg/100 g DM

Abs = Absorbance

t = Cuvette thickness (cm)

$E_{1\,\text{cm}}^{1\%}$ = Extinction coefficient (3450)[27]

Measurement of dry matter, crude fiber, crude protein, ash and organic matter: Dry matter, crude fiber, crude protein, ash and organic matter were analyzed by proximate analysis (AOAC)[28] methods.

Analysis of data: All data in this experiment were analyzed statistically by a one-way ANOVA with a factorial arrangement of treatments in a completely randomized design. The difference among treatment means was performed at a significance level of $p<0.05$ by using a Duncan multiple range test (DMRT) according to Steel and Torrie[29].

RESULTS AND DISCUSSION

Effect of heating method (boiling and steaming) of tomato waste powder on lycopene, dry matter and nutrient content levels: The effects of heating method (boiling and steaming) of tomato waste powder on lycopene, dry matter, crude protein, crude fiber, ash and organic matter levels are shown in Table 1. There was no interaction ($p>0.05$) between heating method and heating duration for lycopene, dry matter, crude protein, crude fiber, ash and organic matter. Heating duration affected lycopene, dry matter, crude fiber, crude protein, ash and organic matter levels significantly ($p<0.05$), while heating method affected ash and organic matter levels significantly ($p<0.05$).

Lycopene content: The optimal lycopene levels occurred for the 12 min heating duration for both boiling and steaming methods. Therefore, both boiling and steaming are effective methods for increasing the lycopene content of tomatoes. The increase in lycopene levels was due to the release of lycopene from the tomato matrix cell by heating. Shi and Le Maguer[30], Colle *et al.*[31] and Thompson *et al.*[9] have stated that heat treatment significantly increases lycopene bioavailability in tomatoes. Before heating, the lycopene in tomatoes is trapped in the matrix of tomato skin tissue and the lycopene in the trans-lycopene structure is difficult for the human body to absorb[30,32,33]. Previous research reported that food processing may improve lycopene bioavailability by breaking down cell walls, which weakens the bonding forces between lycopene and the tissue matrix, thus making lycopene more accessible and enhancing the trans-cis isomerization[30]. Dewanto *et al.*[18] reported that lycopene levels in fresh tomatoes increased after being heated at 88°C for 2, 15 and 30 min to 3.11±0.04, 5.45±0.02 and 5.32±0.05 mg, respectively. Other studies also reported that tomatoes treated by thermal methods released trans-lycopene and cis-lycopene by as much as 4.01±0.48 and

Table 1: Effects of heating method on lycopene, dry matter and nutrient contents of tomato (*Lycopersicon esculentum*) waste

Treatments		Lycopene content (mg/100 g)	Dry matter (%)	Ash (%)	Organic matter (%)	Crude protein (%)	Crude fiber (%)
Heating method (HM)							
Boiling		43.05	4.57	8.63^{B}	91.37^{A}	13.37	11.99
Steaming		42.76	4.73	8.89^{A}	91.11^{B}	13.65	11.79
Heating duration (HD) (min)							
0		34.51^{c}	5.15^{a}	9.28^{a}	90.72^{c}	13.99^{a}	11.24^{c}
4		37.35^{c}	5.13^{a}	9.41^{a}	90.59^{c}	13.90^{a}	11.46^{bc}
8		42.17^{b}	4.85^{a}	8.81^{b}	91.19^{b}	13.72^{a}	11.76^{bc}
12		50.99^{a}	4.33^{b}	8.28^{c}	91.72^{a}	13.43^{a}	12.27^{ab}
16		49.52^{a}	3.79^{c}	8.06^{c}	91.94^{a}	12.50^{b}	12.72^{a}
Interaction of HM and HD							
HM	HD (min)						
Boiling	0	34.51	5.17	9.28	90.72	13.99	11.24
	4	38.84	5.19	9.15	90.85	13.89	10.92
	8	42.02	4.83	8.89	91.11	13.65	11.93
	12	49.88	4.18	8.14	91.86	13.23	12.61
	16	50.01	3.50	7.69	92.31	12.08	13.25
Steaming	0	34.51	5.17	9.28	90.72	13.99	11.24
	4	35.85	5.04	9.67	90.33	13.92	11.99
	8	42.31	4.87	8.73	91.27	13.80	11.60
	12	52.10	4.49	8.41	91.59	13.63	11.93
	16	49.04	4.09	8.42	91.58	12.93	12.18
SEM		0.57	0.09	0.09	0.09	0.23	0.39
Analysis of variance							
HM		ns	ns	*	*	ns	ns
HD		**	**	**	**	**	**
HM X HD		ns	ns	ns	ns	ns	ns

$^{a-c}$Means in a column under similar treatments not sharing the same superscript are significantly different at $p<0.05$, *Means are significant ($p<0.05$), **Means are very significant ($p<0.01$), ns: Not significant

5.04±0.26 μg g^{-1}, respectively and the total lycopene bioaccessibility achieved was 15.6%[34].

This study found that the lycopene content of tomatoes that were heated for 4 min was not different from unprocessed tomatoes but heating durations of 8, 12 and 16 min significantly ($p<0.05$) increased lycopene content. Heating durations of 12 and 16 min did not affect the lycopene content significantly ($p>0.05$). Lycopene content levels in tomatoes heated for 0, 4, 8, 12 and 16 min were 34.51, 37.35, 42.17, 50.99 and 49.52 mg/100 g, respectively. The results of this study are different from those of Thompson *et al.*[9], who reported that the highest lycopene content in tomatoes that were boiled at 100°C for 0, 4, 8 and 16 min, occurred at 8 min. Dewanto *et al.*[18] showed that cooking tomatoes to a temperature of 88°C for 2, 15 and 30 min increased lycopene significantly ($p<0.01$) but there was no difference in results between 15 and 30 min cooking durations.

Dry matter: There was no interaction ($p>0.05$) between heating method and heating duration in tomato dry matter content. Heating duration significantly affected ($p<0.01$) tomato dry matter content but heating method did not affect ($p>0.05$) tomato dry matter content (Table 1). Dry matter content in tomatoes was maintained until the 8 min heating duration was reached in boiling and steaming methods but prolonged heating for 12 min decreased dry matter content significantly ($p<0.05$), while heating tomatoes for 16 min dramatically decreased dry matter content. In this experiment, dry matter content decline was due to the nutrients in tomatoes, such as water-soluble proteins, water-soluble vitamins (vitamin C and B) and macro minerals, dissolved in water during the heating process, either by boiling or by steaming. Protein and mineral content was shown to decrease with decreasing crude protein and ash content in this experiment (Table 1). Tomatoes are known to be high in vitamin C content. Kelebek *et al.*[35], Giovanelli and Paradiso[36] and Gumusay *et al.*[37] reported the vitamin C content in tomatoes to be 277 mg/100 g DM, 330 mg/100 g DM and 310.34±7.23 mg/100 g DM, respectively. Kelebek *et al.*[35] reported that the vitamin C content of tomatoes reduced during the heating process from 329.61-222.04 mg/100 g.

Ash content: There was no interaction ($p>0.05$) between heating method and heating duration for tomato ash content. However, heating method and heating duration both affected ash content significantly ($p<0.05$) (Table 1). Ash content for the boiling method was lower than for the steaming method. Heating for durations of 8, 12 and 16 min decreased ash content. The results show that prolonged heating durations will dissolve large amounts of minerals from tomatoes. Miglio *et al.*[22], Bongoni *et al.*[38] and Mahn and Reyes[39] stated that steaming is the best method for maintaining nutrients in vegetables and Okibe *et al.*[25] reported that the percentage decrease in P, K, Na, Ca, Mg and Fe in *Telfairia occidental* leaves was highest for the boiling method compared to that of steaming and microwaving. Other research showed that the cooking process decreased mineral content in the Asian green mussel (*Perna viridis*)[40]. Another study conducted on sea snails by Purwaningsih *et al.*[41] showed that boiling and steaming decreased calcium, phosphorus, potassium, iron and zinc levels.

Organic matter: There was no interaction ($p>0.05$) between heating method and heating duration in tomato organic matter content. However, heating method influenced organic matter significantly ($p<0.05$) and heating duration affected organic matter content very significantly ($p<0.01$) (Table 1). Organic matter content is higher for boiling than for steaming. Heating for durations of 8, 12 and 16 min increased the organic matter content. This finding is due to the loss of ash during tomato processing, which proportionally increases the organic matter percentage.

Crude protein: There was no interaction between heating method and heating duration for tomato crude protein content. The crude protein content was significantly affected ($p<0.05$) by heating duration but was not significantly affected ($p>0.05$) by heating method (Table 1). The crude protein content was decreased by heating for a duration of 16 min, while heating for durations of 0, 4, 8 and 12 min did not yield different results. This finding indicates that heating duration cannot maintain crude protein content levels for tomato waste. Increasing heating durations reduced crude protein content levels. Kingsley[42] and Nestares *et al.*[43] reported decreased protein content levels in seeds because of cooking and attributed this to the loss of soluble or proteinaceous parts of the seeds into the cooking water. This experiment is in agreement with the results of Tuleun and Patrick[44] that the duration of cooking significantly ($p<0.05$) decreased crude protein, ether extract and nitrogen free extract levels in *mucuna utilis* seed. Purwaningsih *et al.*[45] showed that the boiling and steaming treatment decreased protein content levels in Fasciolaria salmo. Rahma and Mastafa[46] reported that an increase in temperature can cause severe protein damage in foods, ranging from the destruction of amino acids to complete racemization. Okibe *et al.*[25] showed that processing fluted pumpkin (*Telfairia occidentalis*) leaves by steaming, boiling and microwaving for durations of 5 min decreased the percentage of crude protein values by 18.36, 13.54 and 20.36%, respectively.

Crude fiber: In this experiment, there was no interaction ($p>0.05$) between heating method and heating duration for crude fiber content of tomato waste. Heating method (boiling and steaming) also did not significantly affect ($p>0.05$) crude fiber content levels. However, the heating duration did affect crude fiber content significantly ($p<0.05$) (Table 1). Heating durations of 0, 4 and 8 min did not significantly differ in the amount that they affected the crude fiber content of tomato waste. Prolonged heating of tomato waste for 12 min increased crude fiber content at the same significance level at the 4 and 8 min durations and at a significantly lower level than the 16 min duration. The increase of the crude fiber percentage in tomato waste in this experiment is due to the corresponding decrease of the other nutrient content percentages such as crude protein and ash (Table 1) during the process of heating, so that the increase in percentage of crude fiber in this experiment was proportional to the decrease of the other protein and ash percentage.

CONCLUSION

Steaming was the most appropriate method for heating tomato waste based. Heating tomato waste for 12 min was the most appropriate duration for increasing lycopene and organic matter content levels and maintaining crude protein content.

SIGNIFICANCE STATEMENT

This study provides beneficial information to the farmer about the best method for increasing lycopene availability and maintaining the other nutrient content. This study will help other researchers to further investigate the best and most simple methods for farmers to utilize. Thus, a new theory on the best method for increasing lycopene availability and maintaining the other nutrient contents may be established.

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