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Quality Evaluation of Low-fat Pork Loaf Containing Silkworm Powder and Vegetable Worm (*Paecilomyces japonica*) During Cold Storage

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Abstract This study was performed to determine physicochemical and sensory quality of low-fat pork loaf containing silkworm powder and vegetable worm (*Paecilomyces japonica*). Total 2% of fat replacer (soy protein isolate:maltodextrin:κ-carrageenan:water=1:0.5:0.5:10, w/v) was added. The loaf was separated into CTL (control), T1 (0.2% silkworm powder), T2 (0.2% vegetable worm), T3 (0.4% silkworm powder), T4 (0.4% vegetable worm), T5 (0.1% silkworm powder+0.1% vegetable worm), and T6 (0.2% silkworm powder+0.2% vegetable worm). Pork loaf of T3 showed the highest pH value and cooking loss of pork loaves containing silkworm and vegetable worm was higher than control at day 5. 2-Thiobarbituric acid reactive substances of T2 and T5 showed significantly lower values than control and those additives may reduce lipid oxidation of meat. Overall acceptability was not adversely influenced by silkworm powder and vegetable worm at day 0 and 5. These results indicated that those silkworm powder and vegetable worm could be utilized for pork product industry.

Keywords: pork loaf, silkworm powder, vegetable worm (*Paecilomyces japonica*), low-fat

Introduction

An excess fat consumption in the diet has been associated with increases in the incidence of coronary heart disease, obesity, and other related diseases (1). Thus, consumer's food selections have recently focused on low-fat and low-salt types of foods. As a result, the demand for low-fat and low-salt meat products has increased to meet the consumers' demand.

Several *Cordyceps* species are known to be used as traditional medicine and healthy food in the East Asia including China, Japan, and Korea due to their pharmacological and physiological activities (2,3). Li *et al.* (4) reported that *Cordyceps* is commonly used in China to replenish the kidney and soothe the lung, which is related to the treatment of fatigue, night sweating, hyposexualities, hyperglycemia, hyperlipidemia, asthemia after severe illness, respiratory disease, renal dysfunction and renal failure, arrhythmias and other heart disease, and liver disease. However, its usage has been limited during the past decades due to the high price and the difficulty of its supply. The growth of *Cordyceps sinensis* has a very restricted habitat, and the yield is decreasing every year. In 2001, a total of only a few thousands kg of natural *Cordyceps* were collected with a decrease of over 70% as compared to 1978 in China (4). Therefore, much effort has been focused on finding the alternative species. Recently, in Korea, *Paeilomyces japonica* among the *Cordyceps* species was artificially cultivated on a large scale using either the silkworm pupa or larvae, and has started to be consumed as a functional food for cancer prevention and therapy, and immuno-stimulating activities (5).

Inclusion of natural food ingredients containing bioactive functions in processed meat products have been studied by many scientists (6-8). Incorporation of silkworm and vegetable worm may be expected meat product in consumers' demand. However, the suitability of these materials in pork loaf and its quality properties such as water holding capacity, fat emulsification, cooking loss, and sensory quality should be evaluated. The meat loaf was produced by unique oven baking unlike conventional emulsion-type sausage (9). So far, little study was performed to determine the effect of silkworm and vegetable worm on meat loaf quality. Therefore, the aim of this study was to evaluate the influence of silkworm powder and vegetable worm on physicochemical quality, lipid oxidation, and sensory property of pork meat loaf containing fat replacers during cold storage.

Materials and Methods

Materials Fresh pork loin and backfat were purchased from a local market in Jinju, Korea. Silkworm powder and vegetable worm (*Paecilomyces japonica*) were obtained from Nongjin Farm (Hamyang, Gyeongnam, Korea). For the fat replacer, soy protein isolate (SPI, SPI EX-33; Dupon Protein Technologies International, St. Louis, MO, USA), κ-carrageenan (MSC Co., Ltd., Seongnam, Korea), maltodextrin (MD-1520; Corn Products Korea Inc., Seoul,

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Korea), and water were mixed in the ratio of 1:0.5:0.5:10, respectively. Fat replacer was tested each or in combination (data not shown) for optimum quality. The hydrated mixture was added in pork loaf for reducing fat content. Other seasonings and additives were purchased from MSC Co., Ltd. (Seongnam, Korea).

Preparation of pork loaf Recipe of low-fat pork loaf was evaluated by preliminary trials. Manufacturing procedure of pork loaf containing silkworm and vegetable worm powder was shown in Fig. 1. Briefly, the loaf was prepared by mixing ground pork lean and fat with ingredients with 7 different treatments. The mixing was stopped when viscous emulsion was formed (ca. 5-6°C) and 300 g of the emulsion was filled in stainless steel molds. The molds were placed in electric oven and cooked at 180°C until core temperature reached at 70°C. The loaves were then cooled to room temperature, sliced by 15 mm thickness, packaged by low density polyethylene bag, and stored in a walk-in cooler (5°C) for 10 days.

pH Pork loaf sample (5 g) was homogenized with 45 mL of distilled water for 1 min (20,000 rpm) and pH of the homogenates was measured using a pH meter (model EC30; Hacht, Loveland, CO, USA).

Color The cooked pork loaf was put into a round-type quartz cell (3 cm diameter) and CIE color value was measured at day 0, 5, and 10 with a color difference meter (Spectrophotometer CM-3500d; Minolta Co., Ltd., Osaka, Japan). The instrument was calibrated to standard black and white plate before analysis. A large size aperture was used and the measurement was done on triplicated. Data was collected through the computerized system using Spectra Magic Software (version 2.11; Minolta Cyberchrom Inc. Osaka, Japan). CIE L*-(lightness), a*-(redness), and b*-value (yellowness) were calculated according to Jung *et al.* (10).

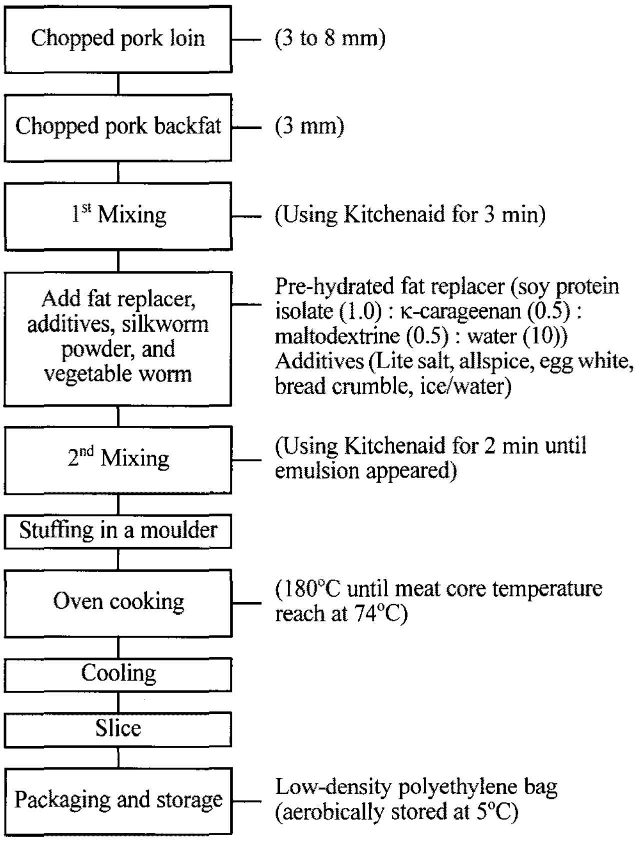

Fig. 1. Manufacturing procedure of low-fat pork loaf.

2-Thiobarbituric acid reactive substances (TBARS) measurement Using the method of Jo and Ahn (7), the TBARS values of the pork loaf containing silkworm powder and vegetable worm were determined. A 5 g sample was homogenized in a 50-mL centrifuge tube with a 50 μL of BHA (7.2% in ethanol) and 15 mL of distilled water by using a homogenizer (DIAX 900; Heidolph Co., Ltd., Schwabach, Germany). One mL of the homogenate was mixed with 2 mL of a thiobarbituric acid (TBA)/ trichloroacetic acid (TCA) solution (20 mM TBA in 15% TCA), heated in boiling water, and centrifuged for 15 min at 300×g by using a centrifuge (UNION 5KR; Hanil Science Industrial, Co., Ltd., Incheon, Korea). The absorbance of the supernatant was measured at 532 nm by using a spectrophotometer (UV 1600 PC; Shimadzu, Tokyo, Japan). The concentration (mg/kg sample on the basis of wet weight) was calculated by using a standard curve.

Cooking loss Pork loaf (200 g) was placed in a 220°C electric oven until the internal temperature reached to 70°C and cooled to room temperature (11). The meat weight was expressed as a percentage of the initial weight.

Sensory evaluation Sensory analysis was performed with semi-trained 12 panelists, including scientists and post-graduate students with at least 1 year experience of sensory analysis for different meat products. The panelists were told about the nature of experiment except for sample identity and requested to evaluate the samples for color, flavor, aroma, juiciness, tenderness, and overall acceptability. Water and no salt-added snack were provided to rinse the panel's mouth between samples. Sensory scores were evaluated with 9-point hedonic scale: 1, extremely poor; 5, normal; 9, extremely desirable (12).

Statistical analysis All measurements were performed in triplicate, and analysis of variance was conducted by the general linear model (GLM) procedure using SAS software (13). Student-Newman-Keul's multiple range tests were used to test for significant differences between the mean values for the treatments. A p-value of less than 0.05 was considered as significant.

Results and Discussion

In our preliminary trial, pork loaf with 15% fat content was developed. Formula of meat loaf containing silkworm and vegetable worm is shown in Table 1. Fat and ice water were contained up to 15 and 13%, respectively.

U.S. Department of Agriculture (14) defined that water and fat content of sausage product should be less than 40% of the product. Especially, fat content of the product should remain no more than 30%. For the production of healthier meat product, health organizations all over the world have

Table 1. Experimental formula of the low-fat pork loaf containing silkworm powder and vegetable worm

Ingredient	Treatment[1)]						
	CTL	T1	T2	T3	T4	T5	T6
Pork loin	55.0	55.0	55.0	55.0	55.0	55.0	55.0
Fat[2)]	15.0	15.0	15.0	15.0	15.0	15.0	15.0
SPI[2)]	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Maltodextrin[2)]	0.5	0.5	0.5	0.5	0.5	0.5	0.5
κ-Carageenan	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lite salt[3)]	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Allspice	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Egg white	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Bread crumble	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Ice/water	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Silkworm powder	-	0.2	-	0.4	-	0.1	0.2
Vegetable worm	-	-	0.2	-	0.4	0.1	0.2

[1)]CTL (control; no addition), T1 (0.2% silkworm powder), T2 (0.2% vegetable worm), T3 (0.4% silkworm powder), T4 (0.4% vegetable worm), T5 (0.1% silkworm powder+0.1% vegetable worm), T6 (0.2% silkworm powder+0.2% vegetable worm).
[2)]Pre-hydrated fat replacer (soy protein isolate:κ-carrageenan:maltodextrin:water=1:0.5:0.5:10, w/v).
[3)]Lite salt (NaCl:KCl)=0.7:0.3.

proposed limits to total fat intake to less than 30% of total calories (8). However this fat reduction cause serious problems in processed meat industry because low-fat meat products tend to be tough, dry, and rubbery, and does not effectively bind water (15). They also had lower shelf-life than regular-fat counterparts due to the high moisture content. Therefore, a gel forming agent can be added to enhance water binding and heat stability in cooked meat product for the retention of added water (16). Currently, carbohydrates and proteins are included in meat product to enhance cooking yield, moisture retention, and texture. In present study, soy protein isolate, κ-carageenan, and maltodextrine were used for this reason. Carrageenans are sulfated polymers of galactose and anhydrogalactose and are produced from red seaweeds. They have 3 main fractions, ι-, κ-, and λ-carrageenans. While ι- and κ-carrageenans have the ability to form thermo reversible gels, λ-carrageenan is a thickener, not a gelling agent (17). As a result of the interaction with water through both ionic and hydrogen bonding, carrageenans are capable of structuring water, thus, have high water binding ability (18). Soy protein additives are also used in many forms such as flours, concentrates, and isolates, and are available in either powdered or textured forms. In meat products such as bologna and frankfurters, the soy proteins could improve water and fat binding and hence aid the emulsion stabilization (19). The main reasons of choosing those fat replacers were for economic benefits (to save on raw material costs) and for improvement of product quality (20). Chin and Chung (21) reported that addition of combined fat replacer in low-fat product showed lower water loss than those of product consisting fat replacer alone. Therefore, in this study mixed fat replacer was used to enhance gellation of the loaves. From the preliminary results, the combination of fat replacer for this study showed similar taste, flavor, and texture characteristics as conventional emulsion meat product.

Addition of silkworm and vegetable worm changed the pH value of low-fat pork loaf during storage at 5°C. As shown in Table 2, the pork loaf added with 0.4% of silkworm powder showed the highest pH value and this remained during whole storage ($p<0.05$). Pork loaves of all treated groups showed higher pH values than that of control ($p<0.05$). Especially, the pH values of T1 and T3 showed higher than other treatment and this may be due to high pH value of silkworm itself. This is well agreed with Kim *et al.* (22) who reported that a silkworm powder showed high protein, and mineral contents, and high pH (8.31) and this weakened gluten structure of bread dough. As storage days increase, pH value decreased in pork loaves of all treated groups.

Table 2. Effects of silkworm powder and vegetable worm on pH of the low-fat pork loaf during storage at 5°C

Treatment[1)]	Storage (day)[2)]			SEM[3)]
	0	5	10	
CTL	5.95^{Ad}	5.95^{Ae}	5.46^{Bd}	0.08
T1	5.96^{Ab}	5.97^{Abc}	5.85^{Bb}	0.02
T2	5.96^{Abc}	5.97^{Acd}	5.69^{Bc}	0.05
T3	5.98^{Aa}	6.00^{Aa}	5.92^{Ba}	0.01
T4	5.95^{Bcd}	5.98^{Ab}	5.89^{Cab}	0.01
T5	5.96^{Ab}	5.96^{Acd}	5.67^{Bc}	0.05
T6	5.96^{Abc}	5.96^{Ade}	5.71^{Bc}	0.04
SEM[4)]	0.001	0.003	0.03	

[1)]CTL (control; no addition), T1 (0.2% silkworm powder), T2 (0.2% vegetable worm), T3 (0.4% silkworm powder), T4 (0.4% vegetable worm), T5 (0.1% silkworm powder+0.1% vegetable worm), T6 (0.2% silkworm powder+0.2% vegetable worm).
[2)A-C, a-e]Means with different superscripts in the same row and column, respectively, significantly differ at $p<0.05$.
[3)]Pooled standard errors of the mean (n=12).
[4)]Pooled standard errors of the mean (n=21).

Lightness (L*) of pork loaf containing silkworm and vegetable worm significantly reduced at day 10 in all

Table 3. Effects of silkworm powder and vegetable worm on color (L*, a*, and b*) of the low-fat pork loaf during storage at 5°C

	Treatment[1)]	Storage (day)[2)]			SEM[3)]
		0	5	10	
L	CTL	73.91^{Aa}	68.61^{Bb}	67.35^{Ca}	1.02
	T1	70.07^{Ab}	65.41^{Bd}	64.35^{Bb}	0.94
	T2	70.15^{Ab}	66.97^{Bc}	61.58^{Cc}	1.26
	T3	67.03^{Ac}	65.37^{Bd}	62.06^{Cc}	0.77
	T4	66.86^{Bc}	69.68^{Ab}	59.69^{Cd}	1.53
	T5	68.37^{Bbc}	73.47^{Aa}	61.31^{Cc}	1.81
	T6	68.32^{Bbc}	72.32^{Aa}	57.74^{Ce}	2.20
	SEM[4)]	0.56	0.68	0.67	
a*	CTL	10.83^{Aa}	11.24^{Aa}	7.10^{Bbc}	0.67
	T1	9.64^{Ab}	8.95^{Ac}	7.46^{Bbc}	0.35
	T2	9.88^{Ab}	10.41^{Ab}	8.17^{Bab}	0.37
	T3	8.30^{Bc}	8.85^{Ac}	6.62^{Cc}	0.34
	T4	9.44^{Bb}	10.65^{Aab}	7.29^{Cbc}	0.50
	T5	9.52^{b}	11.01^{ab}	9.40^{a}	0.36
	T6	9.07^{Bb}	10.90^{Aab}	7.23^{Cbc}	0.55
	SEM[4)]	0.18	0.22	0.23	
b*	CTL	15.30^{A}	12.97^{Bd}	15.68^{Aab}	0.46
	T1	15.39^{A}	13.43^{Bcd}	14.44^{ABbcd}	0.33
	T2	15.72^{A}	14.15^{Bbc}	13.91^{Bcd}	0.36
	T3	15.06	14.90^{b}	14.83^{bc}	0.13
	T4	15.83^{A}	15.12^{ABab}	13.25^{Bd}	0.48
	T5	15.44	14.84^{b}	16.38^{a}	0.38
	T6	15.62^{A}	16.13^{Aa}	13.38^{Bd}	0.47
	SEM[4)]	0.17	0.25	0.28	

1)CTL (control; no addition), T1 (0.2% silkworm powder), T2 (0.2% vegetable worm), T3 (0.4% silkworm powder), T4 (0.4% vegetable worm), T5 (0.1% silkworm powder+0.1% vegetable worm), T6 (0.2% silkworm powder+0.2% vegetable worm).
2)A-C, a-dMeans with different superscripts in the same row and column, respectively, significantly differ at $p<0.05$.
3)Pooled standard errors of the mean (n=12).
4)Pooled standard errors of the mean (n=21).

Table 4. Effects of silkworm powder and vegetable worm on cooking loss (%) of the low-fat pork loaf during storage at 5°C

Treatment[1)]	Storage (day)[2)]			SEM[3)]
	0	5	10	
CTL	14.93^{B}	15.50^{Bc}	18.02^{Abc}	0.51
T1	15.03^{B}	15.88^{ABbc}	17.78^{Abc}	0.50
T2	15.33^{B}	18.36^{Aa}	18.64^{Ab}	0.55
T3	14.70^{B}	17.06^{Aab}	16.91^{Ac}	0.39
T4	14.86^{B}	17.31^{Aa}	17.79^{Abc}	0.47
T5	14.81^{C}	17.35^{Ba}	20.29^{Aa}	0.81
T6	15.50^{C}	17.28^{Ba}	18.63^{Ab}	0.47
SEM[4)]	0.10	0.24	0.24	

1)CTL (Control; no addition), T1 (0.2% silkworm powder), T2 (0.2% vegetable worm), T3 (0.4% silkworm powder), T4 (0.4% vegetable worm), T5 (0.1% silkworm powder+0.1% vegetable worm), T6 (0.2% silkworm powder+0.2% vegetable worm).
2)A-C, a-cMeans with different superscripts in the same row and column, respectively, significantly differ at $p<0.05$.
3)Pooled standard errors of the mean (n=12).
4)Pooled standard errors of the mean (n=21).

Table 5. Effects of silkworm powder and vegetable worm on 2-thiobarbituric acid reactive substances value (mg malondialdehyde/kg meat) of the low-fat pork loaf during storage at 5°C

Treatment[1)]	Storage (day)[2)]			SEM[3)]
	0	5	10	
CTL	0.72^{Ca}	1.71^{Ba}	2.13^{Aa}	0.21
T1	0.63^{Cab}	0.98^{Bb}	1.13^{Ab}	0.08
T2	0.58^{Cab}	0.81^{Bc}	1.26^{Ab}	0.10
T3	0.63^{Bab}	0.85^{Ac}	0.86^{Ac}	0.04
T4	0.49^{Cb}	0.60^{Bd}	0.74^{Ac}	0.04
T5	0.53^{Cb}	0.81^{Bc}	0.92^{Ac}	0.06
T6	0.62^{Bab}	0.76^{ABc}	0.84^{Ac}	0.04
SEM[4)]	0.02	0.08	0.10	

1)CTL (Control; no addition), T1 (0.2% silkworm powder), T2 (0.2% vegetable worm), T3 (0.4% silkworm powder), T4 (0.4% vegetable worm), T5 (0.1% silkworm powder+0.1% vegetable worm), T6 (0.2% silkworm powder+0.2% vegetable worm).
2)A-C, a-cMeans with different superscripts in the same row and column, respectively, significantly differ at $p<0.05$.
3)Pooled standard errors of the mean (n=12).
4)Pooled standard errors of the mean (n=21).

treated groups (Table 3). Especially, pork loaves containing 0.2% of silkworm (T3) and vegetable worm (T4) showed significant reduction of the L*-value ($p<0.05$) compared to that of T1 and T2. The redness (a*) was also significantly influenced by addition of silkworm and vegetable worm. The pork loaf with silkworm powder showed significantly lowered a*-values during storage ($p<0.05$). Yellowness was also highest at day 5 and 10 in T6 and lowest in control.

Compared to control, significantly higher cooking loss was observed in all treated groups at day 5 ($p<0.05$) except for T1 (Table 4). However this tendency was not maintained by day 10 and only T5 showed higher cooking loss than others ($p<0.05$). Cooking the meat cut causes the greatest water loss at 60-70°C and it is presumed that water is expelled by the pressure exerted by the shrinking connective tissue on the aqueous solution in the extracellular void (23). However, in present study, the chopped and minced meat was mixed with water-binding ingredients, such as κ-carrageenan and maltodextrin. Hence, water will migrate on the microscale from the denatured protein to the water-binding ingredients, which will swell (24). The same authors suggested that almost all migration of water is in the form of vapor and this may possible reason of causing cooking loss. Also cooking loss increased as storage day increased regardless of treatments ($p<0.05$) and this may be due to water evaporation during cold storage at 5°C.

During storage, TBARS increased regardless of treatments (Table 5). TBARS of T4 and T5 was significantly lower than that of control ($p<0.05$). This implicated that inclusion of 0.4% vegetable worm and combination of 0.1% of each vegetable worm and silkworm powder may reduce lipid oxidation of pork loaf. This may be due to the antioxidative activity of silkworm powder and vegetable worm (25,26). Ji *et al.* (27) reported that vegetable worm inhibited reactive oxygen and its IC_{50} value was 163 μg/mL. Also

Table 6. Effects of silkworm powder and vegetable worm on sensory evaluation of the low-fat pork loaf during storage at 5°C

Treatments[1)]		Storage (day)[2)] 0	5	10	SEM[3)]
Color	CTL	7.17[Aa]	5.08[B]	3.00[Ca]	0.42
	T1	6.27[Ab]	4.78[B]	2.00[Cb]	0.43
	T2	6.43[Ab]	4.92[B]	3.00[Ca]	0.36
	T3	6.17[Ab]	5.20[B]	2.00[Cb]	0.44
	T4	7.07[Aa]	4.68[B]	2.00[Cb]	0.51
	T5	6.43[Ab]	5.30[B]	2.00[Cb]	0.47
	T6	6.67[Aab]	4.92[B]	2.00[Cb]	0.47
	SEM[3)]	0.09	0.08	0.07	
Flavor	CTL	7.33[A]	4.75[B]	2.50[C]	0.49
	T1	7.17[A]	4.75[B]	2.50[C]	0.47
	T2	6.77[A]	4.87[B]	3.00[C]	0.39
	T3	6.93[A]	5.27[B]	2.50[C]	0.47
	T4	7.10[A]	5.25[B]	2.50[C]	0.48
	T5	7.00[A]	5.20[B]	2.50[C]	0.46
	T6	7.00[A]	5.00[B]	2.50[C]	0.46
	SEM[3)]	0.19	0.09	0.08	
Aroma	CTL	6.83[A]	4.75[B]	2.00[Cd]	0.49
	T1	7.00[A]	4.75[B]	2.00[Cd]	0.50
	T2	7.07[A]	5.08[B]	3.00[Cb]	0.40
	T3	6.83[A]	5.00[B]	2.50[Cc]	0.44
	T4	7.00[A]	4.87[B]	3.50[Ca]	0.36
	T5	7.17[A]	4.80[B]	3.00[Cb]	0.42
	T6	7.07[A]	4.92[B]	2.50[Cc]	0.46
	SEM[3)]	0.05	0.04	0.10	

Table 6. Continued

Treatments[1)]		Storage (day)[2)] 0	5	10	SEM[3)]
Juiciness	CTL	7.17[A]	4.37[B]	3.75[Bb]	0.41
	T1	7.17[A]	4.62[B]	3.50[Cb]	0.42
	T2	7.07[A]	4.25[B]	4.00[Bb]	0.38
	T3	7.33[A]	4.67[B]	3.50[Cb]	0.42
	T4	7.00[A]	4.70[B]	3.50[Cb]	0.39
	T5	7.33[A]	4.50[B]	5.50[Ca]	0.31
	T6	7.33[A]	4.50[B]	4.00[Bb]	0.40
	SEM[4)]	0.11	0.13	0.14	
Tenderness	CTL	6.67[A]	4.62[C]	5.75[B]	0.25
	T1	7.00[A]	4.50[C]	5.50[B]	0.28
	T2	6.93[A]	4.80[B]	5.50[B]	0.26
	T3	6.67[A]	4.88[C]	5.50[B]	0.21
	T4	6.67[A]	5.13[B]	5.50[B]	0.21
	T5	7.00[A]	4.63[C]	5.90[B]	0.27
	T6	7.00[A]	4.97[C]	5.75[B]	0.24
	SEM[4)]	0.05	0.10	0.10	
Overall acceptability	CTL	6.83[A]	4.50[B]	2.50[Cb]	0.45
	T1	6.90[A]	4.50[B]	2.50[Cb]	0.46
	T2	6.77[A]	4.63[B]	3.00[Ca]	0.39
	T3	7.00[A]	5.00[B]	3.00[Ca]	0.42
	T4	7.07[A]	4.97[B]	3.00[Ca]	0.41
	T5	6.90[A]	4.97[B]	3.25[Ca]	0.37
	T6	6.93[A]	4.92[B]	3.00[Ca]	0.40
	SEM[4)]	0.08	0.08	0.06	

[1)]CTL (Control; no addition), T1 (0.2% silkworm powder), T2 (0.2% vegetable worm), T3 (0.4% silkworm powder), T4 (0.4% vegetable worm), T5 (0.1% silkworm powder+0.1% vegetable worm), T6 (0.2% silkworm powder+0.2% vegetable worm).
[2)A-C, a-e]Means with different superscripts in the same row and column, respectively, significantly differ at $p<0.05$.
[3)]Pooled standard errors of the mean (n=12).
[4)]Pooled standard errors of the mean (n=21).

lower content of silkworm powder and vegetable worm powder had synergistically effect on reducing TBARS at day 0. Especially, T4 showed the lowest TBARS value than control and these 2 additives were desirably effect on lipid oxidation of pork loaf during storage for 5 days in cold room (5°C). At day 10, significantly lower TBARS value was shown in T3, T4, T5, and T6 than those of control, T1, and T2, and that was no more than 0.93 mg malondialdehyde (MA)/kg meat. In fact, TBARS values of loaves without silkworm and vegetable worm showed a rapid increase from 0.72 to 2.13 mg MA/kg during 10 days of storage. Increasing ratio of TBARS of control was 66.19% after 10 days cold storage, while those of T3, T4, T5, and T6 were 26.74, 33.78, 42.39, and 26.19%, respectively. Brewer *et al.* (28) suggested that TBARS value of fresh meat and rancid meat is less than 0.2 and more than 4.0, respectively. The result indicated that inclusion of either 0.2% of silkworm powder or 0.2% vegetable worm, and either combination of 0.1% silkworm and 0.1% vegetable worm or 0.2% silkworm and 0.2% vegetable worm significantly reduced lipid oxidation and extended shelf life of the loaves during cold storage.

Sensory characteristics of pork loaves were shown in Table 6. Among the sensory parameters, color is the first factor judging meat product. In this study, inclusion of silkworm and vegetable worm in loaves adversely affected on color, except for control and T4 at day 0 ($p<0.05$). Aroma was not influenced by all treatment at day 0 and day 5, while T4 showed higher score as 3.5 at day 10. Hoffman *et al.* (29) reported that components of the palatability of meat include tenderness, juiciness, and flavour. Tenderness is considered by consumers to be the most important factor of meat quality. In present study, the panelists could not discriminate flavor, juiciness, tenderness, and overall acceptability of loaves among the treatments at day 0 and day 5. However, at day 10, panelists perceived higher juiciness in T5 and higher acceptability in T2, T3, T4, T5, and T6 compared with those of control. From these results, inclusion of silkworm and vegetable worm increased product pH and reduced lipid oxidation and did not show adverse effect on sensory properties of low-fat pork meat loaf and its eating quality could remain as acceptable by day 5 during cold storage. Therefore these additives would be useful to enhance quality of meat loaf. However, further development is needed to compensate the cooking loss of the meat loaf.

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