2015 5th International Conference on Biomedical Engineering and Technology (ICBET 2015)
IPCBEE vol.81 (2015) © (2015) IACSIT Press, Singapore
DOI: 10.7763/IPCBEE. 2015. V81. 11

Physicochemical, Sensory and Cooking Properties of Low Fat Beef Burgers with Addition of Fruit Byproducts and Canola Oil

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Abstract. This study evaluated the addition of canola oil and pineapple, passion fruit and mango byproducts on physicochemical, sensory and cooking properties of burgers. Fourteen formulations were performed: conventional (CN) (20% fat) and formulations with 50% of fat reduction (10% fat): control (CT), without canola oil and fruit byproduct; and 12 formulations with canola oil (5%) and pineapple (PA) or passion fruit (PF) or mango (MA) byproducts in 4 concentrations (1, 1.5, 2, 2.5%). The burgers were analyzed for color, pH, water activity (Aw), cooking loss (CL), moisture retention (MR), fat retention (FR), reduction in diameter (RD), increase in thickness (IT), and sensory characteristics. The byproducts addition decreased CL, RD, IT and increased MR, indicating improvement in yield and better visual characteristics. Lightness was not affected by the byproducts addition and canola oil. PA and MA showed lower a* and higher b* values, respectively. The higher the amount of byproducts added, the lower the pH. Sensory characteristics were not affected by the byproducts and canola oil in the attributes of color, odor and overall acceptance of the burgers. In general, CT had the lowest scores for the attributes. Pineapple byproduct at 1.5% showed the best results as fat substitute in burgers.

Keywords: Mango, passion fruit; pineapple, canola oil, low fat

1. Introduction

Fat has considerable importance in meat products, since it affects technological properties and sensory aspects, mainly tenderness and juiciness. However, diets high in fat provide large amounts of saturated fatty acids and cholesterol, which are associated with the occurrence of obesity, hypertension, cardiovascular disease and coronary heart disease [1].

Due to this, the increase in consumer concern with health has led to changes in eating habits, resulting in increased demand for low fat products. However, in meat products, the simple reduction of fat is not acceptable, mainly regarding texture, juiciness and product yield [2].

Thus, in order to develop low fat meat products of better quality and avoid the mentioned problems, some ingredients have been studied as adjuncts to be incorporated into meat products, acting as animal fat replacers.Vegetables oils and fibers are some of these ingredients used to improve sensory and physical characteristics of low fat meat products.

Vegetable oils are free of cholesterol and they have a higher proportion of unsaturated / saturated fatty acids compared to animal fat [3]. The incorporation of vegetable oils in meat products can be presented as an alternative to minimize the sensory and technological changes of the reduction of animal fat, resulting in

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positive effects on consumer health through calorie reduction, decrease in fat and cholesterol and increase in the content of unsaturated fatty acids.

Agro-industrial activities generate millions of tons of residues all over the world. Although many of them still contain considerable amount of fiber, they have potential for food application. Byproducts from pineapple, mango and passion fruit processing, due to their high fiber contents, have potential to be studied as a food ingredient to improve the technological properties of the product.

The objective of this study was to evaluate the addition of canola oil and different concentrations of pineapple, passion fruit and mango byproducts rich in fiber on physicochemical and sensory characteristics of low fat beef burgers.

2. Material and Methods

2.1. Byproducts Preparation

The byproducts of mango (pomace), pineapple (peel and pomace) and passion fruit (peel, albedo and seed) were collected in a fruit pulp industry, freeze-dried, ground, passed through a 40-mesh sieve and stored under -18°C.

2.2. Burger Manufacture

Fourteen formulations were performed: conventional (CN), with the usual fat amount of beef burger (20%) and formulations with 50% of fat reduction (10%): control (CT), without canola oil and fruit byproduct; and 12 formulations with canola oil (5%) and pineapple (PA) or passion fruit (PF) or mango (MA) byproduct (freeze-dried) in 4 concentrations (1, 1.5, 2, 2.5%) (Table 1).

Table 1: Formulation of beef burgers with addition of canola oil and fruit byproducts (g/100g).

Formulations	Ingredients						
	Beef meat	Pork backfat	Cold water	Canola oil	Fruit byproduct	Salt	Spices
CN	70	20	7.5	-	-	1.5	1
CT	70	10	17.5	-	-	1.5	1
PA 1.0	70	10	11.5	5	1.0	1.5	1
PA 1.5	70	10	11.0	5	1.5	1.5	1
PA 2.0	70	10	10.5	5	2.0	1.5	1
PA 2.5	70	10	10.0	5	2.5	1.5	1
PF 1.0	70	10	11.5	5	1.0	1.5	1
PF 1.5	70	10	11.0	5	1.5	1.5	1
PF 2.0	70	10	10.5	5	2.0	1.5	1
PF 2.5	70	10	10.0	5	2.5	1.5	1
MA 1.0	70	10	11.5	5	1.0	1.5	1
MA 1.5	70	10	11.0	5	1.5	1.5	1
MA 2.0	70	10	10.5	5	2.0	1.5	1
MA 2.5	70	10	10.0	5	2.5	1.5	1

CN: conventional, with 20% fat; CT: control, with 10% fat;
PA 1.0, PA 1.5, PA 2.0, PA 2.5: formulations with 1.0, 1.5, 2.0 and 2.5% of pineapple byproduct, respectively;
PF 1.0, PF 1.5, PF 2.0, PF 2.5: formulations with 1.0, 1.5, 2.0 and 2.5% of passion fruit byproduct, respectively;
MA 1.0, MA 1.5, MA 2.0, MA 2.5: formulations with 1.0, 1.5, 2.0 and 2.5% of mango byproduct, respectively.

For the burger manufacture, beef meat (with fat removed) and pork backfat were ground (5 mm plate). Fat content was determined in both samples in order to adjust the fat amount of the formulations with pork backfat. Beef meat, por backfat, cold water, emulsified canola oil with soy protein isolate (10 parts of oil, 8 parts of water at 50°C and 1 part of soy protein isolate), salt, and spices (salt, maltodextrin, sodium polyphosphate, sodium erythorbate, natural spices and monosodium glutamate) were mixed manually for 3 min. For each treatment, the corresponding proportions of fruit byproducts were added and then mixed again for another 2 min. The doughs (100 g) were shaped (1.0 cm thick and 10 cm diameter) using a burger shaper. The burgers were stored under -18°C. The cooking procedure was performed before the analysis, in a hot plate, until the internal temperature of 75 ℃.

2.3. Cooking Properties

Cooking loss was calculated according to the American Meat Science Association [4]. Moisture retention, fat retention, reduction in diameter and increase in thickness were performed according to the method described by Sánchez-Zapata *et al.* [2]. All these determinations were perfomed in three burgers for each treatment.

2.4. Physicochemical Analysis

Color was determined with a Minolta colorimeter, using the CIELAB system. The pH was performed using a potentiometer with automatic temperature compensation and a glass penetration electrode. Water activity was performed at 25°C, using an Aqualab equipment. All these determinations were perfomed in three burgers for each treatment.

2.5. Sensory Characteristics

Sensory analysis was performed using a hedonic scale of 9 points, ranging from 1 (dislike extremely) to 9 (like extremely). Fifty six panelists evaluated the attributes of color, odor, texture, and overall acceptance. The burgers were cooked according to the same procedure described earlier. The samples were cut into cubes (1.5 x 1.5 x 1.5) and regarding color attribute, a whole burger was presented. The panelists evaluated 5 samples, which were coded with random numbers of three digits. Since there were 14 treatments, the sensory analysis was performed using a balanced incomplete block design, with 56 panelists evaluating 5 samples, with a total of 20 evaluations of each treatment. The protocol for sensory analysis was approved by the local Ethics Committee (ESALQ/University of Sao Paulo, Piracicaba, Brazil – protocol nº 92).

2.6. Statistical Analysis

The study was a randomized block design, with two blocks (two independent processes). For the sensory analysis a balanced incomplete block design was perfomed due to the number of treatments. Significant differences among samples were determined by analysis of variance (ANOVA) and Tukeys HSD test ($p < 0.05$), using the software SAS.

3. Results and Discussion

3.1. Cooking Properties

The addition of fruit byproducts affected the cooking loss of the burgers ($p<0.05$) (Table 2). As the amount of byproducts added increases, the cooking loss decreases. This tendency was observed for the three samples tested (PA, PF, MA), indicanting that the use of fruit byproducts rich in fiber has positive effects for the burger yield. However, significant effect ($p<0.05$) of the cooking loss compared with the conventional burger (CN) was observed just for the treatment PA 2.5%.

This higher yield of burgers with PA, followed by burgers with passion fruit and mango, could be related to the fiber content and water holding capacity (WHC) of the byproducts, which presented the following descending order: pineapple (69.64 g fiber/100 g sample and WHC of 4.96 g water/g sample) > passion fruit (56.93 g fiber/100 g sample and WHC of 4.51 g water/g sample) > mango (31.57 g fiber/100 g sample and WHC of 2.87 g water/g sample) (previous experiment, unpublished data). Similar results were found by López-Vargas *et al.* [5], who verified that, compared with control treatment, samples with addition of passion fruit albedo showed an increased cooking yield and it occurred in a concentration-dependent manner, with no statistical differences among samples.

According to Kastner and Felicio [6], the meat grinding during burger processing results in a tender product due to the breakdown of the myofibrils and connective tissue, which, however, promotes weight loss during the cooking process. This factor results in the release of fluids, such as water, water-soluble nutrients, color pigments and compounds responsible for flavor and odor [7]. Thus, the addition of fruit byproducts in beef burger, especially pineapple byproduct, showed positive results, increasing yield and reducing the release of important compounds of the product. Treatments with the lowest byproduct amount showed similar CL values to the control, indicanting that, concentrations equal ou below 1.0% do not improve yield.

Comparing the moisture retention among treatments with the same byproduct concentration, in general, burgers of the treatment PA showed higher moisture retention, which, in the formulations PA 2.0% and PA

2.5% resulted in significant higher values ($p<0.05$) than the observed in the conventional treatment (Table 2). For the treatments PF and MA, with exception of PF 2.5%, there was no significant difference ($p>0.05$) among them.

Table 2: Cooking properties of burgers with addition of fruit byproducts and canola oil (average ± standard deviation)

Treatament	Cooking loss (%)	Moisture retention (%)	Lipid retention (%)	Reduction in diameter (%)	Increase in thickness (%)
CN	38.64±1.55 abc	57.22±2.63 abc	53.58±3.04 b	24.40±0.07 a	23.70±4.18 abcd
CT	42.21±0.84 ab	46.22±1.19 de	83.50±0.40 a	24.65±4.13 a	13.04±4.08 d
PA 1.0	41.21±5.82 ab	46.86±7.84 de	77.07±8.99 ab	26.08±2.79 a	27.14±2.11 ab
PA 1.5	34.20±1.34 bc	54.80±0.82 bcd	78.97±1.65 ab	20.63±2.68 ab	19.20±3.11 bcd
PA 2.0	30.56±2.54 cd	59.16±3.50 ab	82.83±2.96 a	19.28±1.62 ab	19.26±2.81 bcd
PA 2.5	24.91±4.91 d	65.20±5.01 a	92.59±8.95 a	16.98±0.63 b	14.20±0.97 cd
PF 1.0	43.88±6.50 a	43.30±5.81 e	75.93±11.57 ab	24.64±0.89 a	20.37±4.05 abcd
PF 1.5	40.27±2.01 ab	47.69±2.78 de	75.53±2.13 ab	22.74±0.88 ab	19.61±4.86 abcd
PF 2.0	36.66±0.36 abc	51.31±2.83 bcde	79.54±10.22 ab	21.40±2.38 ab	18.09±1.67 bcd
PF 2.5	35.80±0.25 abc	52.63±1.34 bcd	77.24±11.40 ab	21.72±1.84 ab	26.80±0.89 ab
MA 1.0	41.30±2.34 ab	47.27±3.60 de	75.71±4.05 ab	23.83±0.54 ab	19.79±0.39 abcd
MA 1.5	38.70±0.22 abc	50.57±0.59 bcde	70.91±1.23 ab	23.97±1.63 ab	27.91±0.56 ab
MA 2.0	39.44±1.25 ab	48.31±1.73 cde	77.73±1.64 ab	24.09±2.99 ab	24.38±1.56 abc
MA 2.5	37.58±1.65 abc	51.12±3.71 bcde	73.48±4.19 ab	23.79±0.42 ab	30.38±1.83 a

Different letters in the same column differ significantly ($p\leq0.05$) by the Tukey HSD test.

The results observed for moisture retention can also be explained by the property of the fiber to hold water. Since pineapple byproduct has the higher amount of fiber, consequently it showed a higher water holding capacity, which, when used as a food ingredient in beef burger, resulted in products with higher percentages of moisture retention. This result is importante since high retention of both water and fat, positively influences characteristics such as texture and juiciness of meat products.

Aleson-Carbonell *et al.* [8] working with lemon albedo and López-Vargas *et al.* [5] studying passion fruit albedo also observed increase in moisture retention of burgers with addition of rich in fiber ingredients.

Regarding fat retention, conventional treatment presented the lowest value compared to the others (Table 2). According to Besbes *et al.* [9], fat retention is related to the capacity of the meat matrix to bind fat. Thus, this lower retention of CN may be occurred because it has twice the fat content, but the same amount of beef meat compared to the other treatments. In other words, the amount of protein derived from beef may not have been sufficient to retain the added fat (only 53.58 % was retained), whereas, in other samples, the retention ranged from 70.91 to 92.59%.

Among treatments with the same fat content (control and formulations PA, PF and MA), only the ones with the higher concentrations of pineapple byproduct had higher, but not significant values ($p> 0.05$) compared to the control. This result can be explained by the low CRO of the lyophilized byproducts, which varied from 1.57 to 1.85 g oil/100 g sample (previous experiment, unpublished data).

Burgers with addition of pineapple byproduct showed the lowest reduction in diameter and only the treatment AB 2.5% had significant difference ($p <0.05$) compared with CN and CT (Table 2). The reduction in diameter is a result of meat protein denaturation with the loss of water and fat during cooking [5]. Thus, since pineapple byproduct showed the highest water and oil holding capacity and resulted in burgers with higher moisture and fat retention, these facts consequently led to products with higher diameters.

The results obtained are in concordance with Turhan, Sagir e Ustun [10] with low-fat beef burgers incorporated with hazelnut pellicle and in the study of Tekin, Saricoban, Yilmaz [11] in burgers with addition of wheat bran.

In the formulations PA and PF, with the increase of the byproduct concentration and consequent increase of the fiber content in the burgers, probably there was compensation in the dimensional parameters, leading to burgers with larger diameters and smaller thickness. According to the study of López-Vargas *et al.* [5] with passion fruit albedo, the same behavior was observed in pork burgers, which, according to the author, could be attributed to binding properties and stabilization of the passion fruit albedo, limiting the distortion of the products during cooking.

3.2. Physicochemical Properties

Color evaluation showed that neither the fat reduction nor the addition of fruit byproducts and canola oil significantly affected the L* value of the burgers, both raw and cooked (Table 3). These results differ from those obtained by Lopez-Vargas *et al.* (2014) in pork burger with addition of passion fruit albedo and obtained by Turhan, Sagir and Ustun (2005) in beef burger with hazelnut pellicle.

The fact that the luminosity of the samples was not altered by the treatments is considered positive, since in meat and meat products color is an important quality attribute and one of the main factors determining the acceptability of the consumer, which can be influenced by the concentration and chemical state of myoglobin, by the physical characteristics of the meat and by the presence of non-meat ingredients [12].

Table 3: Color of raw and cooked burgers with addition of fruit byproducts and canola oil (average ± standard deviation)

Treatments	Raw burger			Cooked Burger		
	L*	a*	b*	L*	a*	b*
CN	51.00±4.61 ^{a}	21.95±0.96 ^{a}	14.55±1.73 ^{a}	47.57±0.88 ^{a}	8.22±0.01 ^{a}	11.73±0.33 ^{de}
CT	47.57±0.80 ^{a}	20.25±2.85 ^{ab}	13.81±2.20 ^{a}	50.08±1.34 ^{a}	7.90±0.18 ^{ab}	11.33±0.32 ^{e}
PA 1.0	47.59±0.83 ^{a}	18.60±0.36 ^{abc}	14.37±0.48 ^{a}	50.35±1.87 ^{a}	7.39±0.18 ^{abc}	11.69±0.73 ^{de}
PA 1.5	47.90±0.45 ^{a}	18.67±0.89 ^{abc}	15.61±0.51 ^{a}	50.06±1.97 ^{a}	6.78±0.07 ^{bcd}	11.84±0.65 ^{cde}
PA 2.0	47.22±0.51 ^{a}	17.36±0.20 ^{bc}	15.28±0.21 ^{a}	49.42±2.88 ^{a}	6.13±0.74 ^{d}	12.29±0.50 ^{bcde}
PA 2.5	50.05±3.14 ^{a}	15.80±0.41 ^{c}	16.06±0.35 ^{a}	51.59±0.27 ^{a}	6.30±0.46 ^{cd}	13.41±0.10 ^{abc}
PF 1.0	50.60±2.31 ^{a}	18.51±0.13 ^{abc}	14.26±0.65 ^{a}	51.14±0.23 ^{a}	7.69±0.64 ^{ab}	12.94±0.16 ^{bcde}
PF 1.5	50.70±1.35 ^{a}	18.82±0.01 ^{abc}	15.07±0.01 ^{a}	51.24±1.46 ^{a}	7.63±0.61 ^{ab}	13.20±0.07 ^{abcd}
PF 2.0	51.27±1.67 ^{a}	18.66±0.86 ^{abc}	14.89±0.14 ^{a}	51.06±1.31 ^{a}	7.27±0.13 ^{abcd}	13.04±0.35 ^{abcd}
PF 2.5	51.26±0.57 ^{a}	18.22±1.28 ^{bc}	15.32±0.10 ^{a}	51.15±0.50 ^{a}	7.31±0.10 ^{abcd}	13.50±0.04 ^{ab}
MA 1.0	50.77±1.23 ^{a}	19.93±1.58 ^{ab}	15.05±0.62 ^{a}	48.63±1.75 ^{a}	7.41±0.25 ^{abc}	13.04±0.58 ^{abcd}
MA 1.5	51.19±3.15 ^{a}	19.03±1.39 ^{abc}	15.17±0.02 ^{a}	48.73±3.02 ^{a}	7.49±0.13 ^{abc}	13.14±0.65 ^{abcd}
MA 2.0	51.39±0.46 ^{a}	19.13±0.76 ^{abc}	15.79±0.38 ^{a}	49.15±2.71 ^{a}	7.76±0.20 ^{ab}	13.75±0.34 ^{ab}
MA 2.5	51.81±0.97 ^{a}	19.03±0.71 ^{abc}	16.45±0.17 ^{a}	48.56±2.68 ^{a}	7.77±0.28 ^{ab}	14.60±0.28 ^{a}

Different letters in the same column differ significantly ($p \leq 0.05$) by the Tukey HSD test.

In relation to the a* value, it was not strongly influenced by the addition of fruit byproducts, since only the treatments with the higher levels of pineapple byproduct showed significant reduction ($p < 0.05$) in redness compared to the conventional treatment. This result may be due to the influence of the color of the pineapple byproduct on the natural color of the meat, since according to Table 3, its addition promote the lowest L *, a * and b * values. Decreases in a* values were also reported by Turhan, Sagir and Ustun (2005) in beef burger with hazelnut pellicle and by Choi et al. [13] in low fat pork burger with addition of seaweed (*L. japonica*).

In cooked burgers with 2.5% of fruit byproducts there was a significant increase ($p < 0.05$) in the intensity of yellow color compared to CN (20% fat) and CT (10% fat without addition of fruit fiber and canola oil). The addition of mango byproduct promoted the greatest change in b* value, corroborating with the color evaluation of the byproducts, which indicated b* values of 42.18, 20.65 and 28.62 for mango, pineapple and passion fruit, respectively (previous experiment, unpublished data). The raw products did not present significant effect ($p > 0.05$) for yellowness.

There was significant effect ($p < 0.05$) of the addition of fruit byproducts on the pH of the beef burgers, both raw and cooked (Table 4).

In general, it was observed that the higher the amount of fruit byproduct added, the lower the pH of the samples, and that this decrease was significant ($p < 0.05$) compared to CN only in the formulations with the higher levels of addition. Among the treatments, the lowest pH values were observed in those with passion fruit byproduct, followed by PA and PF. These results were certainly influenced by the characteristics of each byproduct, since according to a previous experiment (unpublished data) passion fuit presented the lowest pH and the higher acidity among the byproducts studied here.

Comparing the pH results of the raw and cooked products, it could be observed that the cooking process increased the pH of the samples. According to Choi *et al.* [13], the pH increases when meat products are heated because imidazolium, which is a base in histidine amino acids, is exposed during cooking due to the protein denaturation.

Table 4: pH values and water activity of raw and cooked burgers with addition of fruit byproducts and canola oil (average ± standard deviation)

Treatments	pH		Aw	
	Raw burger	Cooked Burger	Raw burger	Cooked Burger
CN	6.12±0.25 a	6.49±0.14 a	0.97±0.00 a	0.96±0.00 a
CT	6.04±0.08 ab	6.45±0.23 ab	0.98±0.00 a	0.96±0.00 a
PA 1.0	5.93±0.11 abc	6.42±0.25 ab	0.97±0.00 a	0.95±0.01 a
PA 1.5	5.89±0.12 abcd	6.43±0.23 ab	0.97±0.00 a	0.96±0.00 a
PA 2.0	5.88±0.09 bcd	6.36±0.23 ab	0.97±0.00 a	0.96±0.00 a
PA 2.5	5.86±0.13 bcd	6.32±0.22 bc	0.97±0.00 a	0.96±0.00 a
PF 1.0	5.94±0.18 abc	6.40±0.25 ab	0.97±0.00 a	0.95±0.00 a
PF 1.5	5.81±0.11 cd	6.30±0.24 bc	0.97±0.00 a	0.96±0.00 a
PF 2.0	5.75±0.12 cd	6.17±0.14 dc	0.97±0.00 a	0.95±0.01 a
PF 2.5	5.68±0.12 d	6.13±0.19 d	0.97±0.00 a	0.95±0.00 a
MA 1.0	5.97±0.06 abc	6.45±0.23 ab	0.97±0.00 a	0.96±0.00 a
MA 1.5	5.90±0.05 abcd	6.41±0.20 ab	0.97±0.00 a	0.96±0.00 a
MA 2.0	5.77±0.17 dc	6.35±0.20 ab	0.97±0.00 a	0.95±0.00 a
MA 2.5	5.84±0.02 bcd	6.31±0.14 bc	0.97±0.00 a	0.96±0.00 a

Different letters in the same column differ significantly ($p \leq 0.05$) by the Tukey HSD test.

The results of this study are in agreement with the study of Aleson-Carbonell *et al.* [8] in beef burger with addition of lemon albedo. However, the study by Gök *et al.* [14] did not find effect of poppy seeds addition on the pH of beef burgers.

Regarding the Aw values, despite the fact that the fruit byproducts studied here presented significant amount of fiber in its composition, which has the capacity to retain water, this property did not significantly affect ($p > 0.05$) the water activity of both raw and cooked burgers, which is an important result since high values {}of Aw could favor microbial growth. There was reduction in the Aw of the cooked burgers, which was expected, since during cooking process, part of the water is eliminated.

3.3. Sensory Characteristics

The results of the acceptance test were positive, since it was not observed significant effect ($p > 0.05$) of the addition of different fruit byproducts and canola oil in the attributes of color, odor and overall acceptance of beef burgers (Table 5).

For the texture attribute, panelists indicated the lowest score for the control treatment (4.31), which is between "indifferent" (5) and "slightly dislike" (4) terms. Fat strongly influences the texture and juiciness of meat products and since CT treatment had the reduction of 50% of fat without the addition of fiber and vegetable oil, this slight rejection could be due to hardness and low juiciness of the product.

Table 5: Sensory attributes of burgers with addition of fruit byproducts and canola oil (average ± standard deviation)

Treatment	Color	Odor	Texture	Overall Acceptance
CN	6.20±0.21 a	6.10±0.35 a	6.10±0.49 ab	5.95±0.14 a
CT	6.17±0.32 a	5.75±0.35 a	4.31±0.20 b	5.68±0.10 a
PA 1.0	6.20±0.00 a	6.43±0.32 a	6.62±0.09 a	6.13±0.11 a
PA 1.5	6.10±0.21 a	6.48±0.39 a	6.63±0.67 a	6.00±0.49 a
PA 2.0	6.69±0.08 a	6.59±0.06 a	6.95±0.22 a	6.72±0.32 a
PA 2.5	6.88±0.95 a	6.28±0.17 a	6.73±0.04 a	6.78±0.88 a
PF 1.0	6.80±0.36 a	6.59±0.19 a	5.28±0.31 ab	6.39±0.62 a
PF 1.5	6.88±0.46 a	6.02±0.11 a	4.98±1.23 ab	6.50±0.42 a
PF 2.0	6.33±0.88 a	5.97±0.12 a	5.84±0.65 ab	5.90±0.85 a
PF 2.5	7.15±0.49 a	6.25±0.85 a	6.50±0.00 ab	6.68±0.81 a
MA 1.0	6.62±0.46 a	6.67±0.31 a	5.93±0.89 ab	6.24±0.41 a
MA 1.5	6.38±0.18 a	6.63±0.18 a	6.11±0.15 ab	6.38±0.46 a
MA 2.0	6.30±0.64 a	6.83±0.04 a	6.43±0.04 ab	6.15±0.85 a
MA 2.5	6.70±0.07 a	6.62±0.02 a	6.08±0.25 ab	6.45±0.21 a

Different letters in the same column differ significantly ($p \leq 0.05$) by the Tukey HSD test.

There was no significant difference (p>0.05) among treatments with byproducts addition for the texture attribute. However, samples with PA had slightly higher scores, which may be due to higher moisture retention of the product, positively affecting tenderness and juiciness. Despite of the higher scores, treatments with 2.0 and 2.5% of pineapple byproducts presented problems of cracking and breakage after cooking, probably due to the high water retention of the fibers.

The treatments MR had the lowest texture scores, which could be due to the high amount of soluble fiber in the passion fruit byproduct (8.90 g/100 g sample) (previous experiment, unpublished data). Soluble fibers bind to water and form gels, which may have given some elasticity and resistance to chewing, affecting negatively the texture of the burger.

Except for color, in the other attributes control treatment had the lowest scores, which is in agreement with the fact that fat reduction of meat products, by simply decreasing its quantity, is not acceptable from the sensory point of view.

4. Conclusions

The addition of byproducts positively affected the cooking properties of beef burgers. A the byproducts studied, treatments with pineapple byproduct showed the best results, leading to a decrease in the parameters of cooking loss, reduction in diameter, and increase in thickness and an increase in the moisture retention, resulting in improvement in yield and better visual characteristics.

Lightness and water activity was not affected by the presence of fruit byproducts and canola oil. Formulations with higher amount of pineapple and mango byproducts showed lower a*values and higher b* values, respectively. However, in the sensory analysis of color, panelists did not detect color alteration due to byproducts and canola oil addition.

Sensory characteristics showed positive results, since there was no effect of the byproducts and canola oil addition in the attributes of color, odor and overall acceptance of the burgers. In general, control treatment had the lowest scores for the attributes evaluated, confirming that the simple reduction of fat is not sensory acceptable. The texture was affected by the addition of fruit byproducts, with the treatment PA presenting slightly higher scores.

According to the cooking properties, physicochemical and sensory characteristics, pineapple byproduct at the concentration of 1.5% showed the best results as fat substitute in beef burgers.

5. Acknowledgment

The authors acknowledge the “Fundação de Amparo à Pesquisa do Estado de São Paulo”, for financial support (n^{o} 2012/03347-9).

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