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Effect of ginger powder addition on quality, fatty acids profile, lipid oxidation and antioxidant capacity of cooked pork burgers

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Abstract

Ginger powder effects were evaluated in cooked pork burgers after a refrigerated storage as raw meat products at 4 °C up to 7 days. Physical-chemical characteristics, fatty acids profile, lipid oxidation and antioxidant capacity of burgers were tested in control samples (only meat, C) and in two formulations containing 1% and 2% of ginger powder (G1 and G2). Ginger naturally brought yellow pigments that increased b* index of G2 burgers. Colour variations between C and G2 were also visible by human eyes as showed by ΔE indices. Ginger improved PUFAω3 and PUFAω6 percentages to the detriment of SFA with following decreases of atherogenicity and thrombogenicity indices. Antioxidants present in ginger powder reduced lipid oxidation (TBARS) and increased antioxidant capacity (FRAP, ABTS and DPPH) of burgers. Results highlighted that ginger

powder could express increasing the antioxidant capacity and reducing lipid oxidation of burgers with the final income of healthier products than the control ones.

Keywords

Cooked burger; Meat quality; Natural antioxidant; Ginger; Antioxidant capacity.

1. Introduction

Ready to cook and ready to eat meat products are one of the more reliable protein foods sold in markets. Particularly, burgers (or patties) represent one of the most consumed products due to their easiness to be stored and the short time requested to be cooked. Due to grinding process burgers are more susceptible to oxidation and microbial spoilage than unprocessed meat because of disruption of muscle structure and the formation of a less stable food matrix that could occur more easily into chemical and enzymatic oxidation [1, 2]. During the last decades several research studies were conducted with the aims to enhance shelf life of burgers, as well as their nutritional value. Production processes, packaging technologies and food additives were studied and employed with the main aim to reduce oxidation [3–5].

In order to control food lipid oxidation and deterioration several synthetic additives with antioxidant properties were widely used (i.e. butylated hydroxyanisole or BHA and butylated hydroxytoluene or BHT). This trend changed few years ago after deeply evaluations of synthetic additives that highlighted potential toxic effects and the following consumers behaviour to avoid food that contain these types of additives [6, 7].

Natural antioxidants seem to be one of the most reliable responses to this issue, as most of them are not related to side effects and are well accepted by consumers [8, 9].

Essential oils, extracts, powders and other plant products were largely studied, and several studies had demonstrated their positive activity against lipid oxidation in meat products [4, 10]. Spices had been used for centuries for their large number of properties. From a technological point of view, they can modify the physical-chemical characteristics of the product or reduce the growth of spoilage bacteria, from a sensory point of view they can affect the colour, taste, flavour and texture. Among Zingiberaceae family ginger, *Zingiber officinale* Roscoe, is one of the most studied as food additive due to its strong antioxidant profile [11–14] and it is a well-known spice used in different types of dishes [15]. Commonly ginger is used both fresh or dried, anyhow, as powder it is more stable and useful in food industries as ingredient in meat products. Ginger powder was largely

studied for its important content of antioxidant molecules such as phenols, terpenoids and flavonoids [16, 17]. Furthermore, through the drying process antioxidant capacity of ginger could be enhanced with the formation of shogaols from the dehydration of gingerols. Indeed, shogaols exhibit higher biological properties than gingerols including anticancer and antioxidant activities [18–20].

Several articles reported the effects of spices in raw meat burgers, anyhow, a small number of data are available about how spices could contribute to the chemical and physical characteristics of cooked products (i.e. ready to eat).

For the reasons reported above the main aims of this study were to quantify the effects of a well-known spice, ginger, in a cooked meat product. Effects of two concentrations of ginger powder on meat quality parameters (pH, colour and water holding capacity), fatty acid profile, lipid oxidation and antioxidant capacity of burgers added with natural antioxidant before cooking were studied. Furthermore, storage time up to 7 days was applied on raw burgers before cooking in order to assess if ginger powder might enhance shelf life of burgers.

2. Material and methods

2.1. Experiment design and burgers formulations

Burgers were formulated as reported by Mancini et al. [21]. Nine experimental units, each one consisting in Longissimus lumborum muscle from one pig, were randomly assigned to three formulations (3 experimental units per formulation). Each muscle was singularly minced for a total of nine meat batches. Three formulations (F) were manufactured: control burgers (C, only meat), burger added with 1% of ginger powder (G1, 10 g of ginger per kg of meat) and burgers added with 2% of ginger powder (G2, 20 g of ginger powder per kg of meat). Ginger powder was purchased from wholesaler Drogheria e Alimentari S.p.A. (Scarperia e San Piero, Florence, Italy; rhizomes of ginger from India, batch number L65069N, proximate composition, antioxidant capacity, colour and fatty acids profile of ginger powder are reported in Table 1) as a ready to use food ingredient. From each experimental unit 10 burgers were prepared (85 mm diameter, 100 g) for a total of 30 burgers per F and an overall number of 90 burgers. Proximate analysis of meat batches reported in Mancini et al. [21] (moisture: 71.56% ± 0.68; ether extract: 2.23% ± 0.45).

Samples were stored at 4 °C for 1, 4 and 7 days (storage time - ST, D1, D4, D7) in single Styrofoam trays overwrapped with polyethylene film. At each ST three burgers for each experimental unit were cooked in a preheated oven at 163 °C to an internal temperature of 71 °C (burgers were turned

every 4 min to prevent excess surface crust formation as reported by American Meat Science Association, AMSA [22]). Internal temperature of burgers was monitored by opening the oven every 4 minutes, when burgers were turned, a variation of 1 °C of their internal temperature was tolerated (measured by a portable thermocouple thermometer; HI 92704C, Hanna Instruments, Padova, Italy). After cooking, the surfaces of the burgers were dried slightly with blotting paper and the burgers were held at room temperature (set at 25 °C) until them cooled down. Cooked burgers were analysed for the determination of pH, colour, fatty acids profile, lipid oxidation (TBARS) and antioxidant capacity (ABTS, DPPH and FRAP).

2.2. pH and colour determination

The pH was determined with a puncture electrode (Double Pore Slim, Hamilton, Switzerland) equipped on a pH meter with automatic temperature compensator (pH 2700, Eutech Instruments, The Netherlands). pH meter was calibrated before each session with buffer solutions at pH 4.01 and 7.01 (HI7004L and HI7007L Hanna instruments, Italy).

Colour indices [23] as lightness (L*), redness (a*) and yellowness (b*) were recorded with a Chroma meter Minolta CR300 (Minolta, Japan) with an aperture size of 8 mm, illuminant D65 and incidence angle of 0°. Before each session, the colorimeter was calibrated with a white tile (L* = 98.14, a* = −0.23 and b* = 1.89).

Chroma (C*) and hue angle (H*) were calculated from a* and b* indices as reported by Commission Internationale de l'Éclairage (CIE) [23]. Moreover, numerical total colour difference (ΔE) was calculated as proposed by Sharma and Bala [24] between different F at the same ST (effect of the formulation) or between different ST of the same F (effect of the storage time). Moreover, colour changes after cooking were calculated between raw and cooked samples for all the F and ST (colour of raw samples were previously published by Mancini at al. [21]).

2.3. Fatty acids profile

Fatty acids were extracted and processed via transesterification with methanol [25]. FAMEs (fatty acid methyl esters) were analysed by gas chromatography and separated with an Agilent capillary column (30 m × 0.25 mm I.D., CPS Analitica, Italy) coated with a DB-Wax stationary phase (film thickness of 0.25 µm). The operating conditions of the column injection were as follows: the temperatures of the injector and detector were 270 and 280 °C, respectively and the detector gas flows were H_2 50 mL/min and air 100 mL/min. The oven temperature was programmed to give good

peak separation; the initial temperature was set at 130 °C and then increased at a rate of 4.0 °C/min until reaching a temperature of 180 °C, which was held for 5 min; the temperature was subsequently increased at a rate of 5.0 °C/min until it reached 230 °C, which was held for 5 min. Helium was used as a carrier gas at a constant flow rate of 1.5 mL/min. Individual fatty acid methyl esters were identified with reference to the retention time of FAME mixture (Sigma-Aldrich, Germany) and calculated with the internal standard method (nonadecanoic acid, C19:0).

Results were expressed as percentage of singular fatty acids on total FAME using the peak areas.

Atherogenicity (AI), thrombogenicity (TI), hypocholesterolemic (h), hypercholesterolemic (H) and peroxidisability (PI) indices were calculated as reported below following the formulas proposed by Ulbricht and Southgate [26] and Santos-Silva et al. [27]:

AI: $(C12{:}\,0 + C14{:}\,0 * 4 + C16{:}\,0)/(MUFA + PUFA\omega3 + PUFA\omega6)$

TI: $(C14{:}\,0 + C16{:}\,0 + C18{:}\,0)/\,(MUFA * 0.5 + PUFA\omega6 * 0.5 + PUFA\omega3 * 3 + PUFA\omega3\,/PUFA\omega6)$

h/H: $(C18{:}\,1 + C18{:}\,2\omega6 + C18{:}\,3\omega3 + C18{:}\,3\omega6 + C20{:}\,4\omega6 + C20{:}\,5\omega3 + C22{:}\,6\omega3)/(C14{:}\,0 + C16{:}\,0)$

PI: $\sum monoenoic * 0.025 + \sum dienoic * 1 + \sum trienoic * 2 + \sum tetraenoic * 4 + \sum pentaenoic * 6 + \sum hexaecoic * 8$

2.4. Lipid oxidation (TBARS - Thiobarbituric acid reactive substances)

Samples (5 g) were extracted with trichloroacetic acid (TCA, 7.5%) and diethylenetriaminepentaacetic acid (DTPA, 0.1%) as proposed by Dal Bosco et al. [28]. The extracted samples were mixed with 2-thiobarbituric acid (TBA, 0.288%) and placed in water bath at 95 °C for 45 min. Samples absorbance were determined at 532 nm (V-530 Jasco International, Italy) against a blank containing TCA/DTPA. Results were expressed as mg malondialdehyde equivalent (MDA-eq) per kg of meat using a calibration curve of TEP (1,1,3,3-tetraethoxypropane, 0-15 µM).

2.5. Antioxidant capacity

Samples (5 g) were extracted with ethanol as reported by Mancini et al. [29] and extracts were used to quantify the antioxidant capacity to reduce ABTS - 2,2'-azinobis(3-ethylbenzothiazoline-6-sulphonic acid as reported by Re et al. [30], DPPH - 2,2-diphenyl-1-picrylhydrazyl as reported by Blois [31] and TPTZ-FeCl3 - complex 2,4,6-tris(2-pyridyl)-*S*-triazine with Fe(III) chloride (FRAP method) as described by Descalzo et al. [32].

Antioxidant capacity was expressed as mmol equivalent of Trolox per kg of sample for both ABTS and DPPH methods and as mmol equivalent of Fe(II) per kg of sample for FRAP method.

159

160 2.6. Statistical analysis

161 Two-ways ANOVA was used to analyse the effect of the formulation (F) and the storage time (ST) on
162 physical-chemical characteristics (pH, L*, a*, b*, C* and H*), fatty acids profile (single, sums and
163 calculated indices), lipid oxidation (TBARS) and antioxidant capacity (FRAP, ABTS and DPPH) of
164 burgers. The following linear model was used: $Yijz = \mu + \alpha i + \beta j + \alpha\beta ij + eijz$, where Yijz is the
165 dependent variable of the zth observation; μ is the overall mean; αi is the effect of the F (i = C, G1,
166 G2); βj is the effect of the ST (j = D1, D4, D7); αβij is the effect of the interaction between F and ST
167 (F × ST), and eijkz is the random error. When the interaction F × ST was not significant ($P<0.05$) the
168 results were reported as functions of the main effects F and ST. When the effect showed a significant
169 variation ($P<0.05$) means were compared using Tukey's test.
170 A principal component analysis was conducted to determinate the relationship between pH, colour,
171 fatty acids profile, lipid oxidation (TBARS) and antioxidant capacity (ABTS, DPPH and FRAP); all the
172 data were mean centred and scaled to a unit standard deviation before analysis.
173 The R free software was used for the statistical analysis [33].
174

175 **3. Results and discussion**

176 Neither the F nor the ST affected the pH of the cooked burgers which presented an overall mean of
177 6.25 (Table 2). Considering the colour parameters, the addition of 2% of ginger powder to the meat
178 increased the yellowness of the burgers and consequently the levels of C* and H* (as b* is part of
179 the both C* and H* calculation formulas) ($P<0.001$, $P<0.01$ and $P=0.001$, respectively for b*, C* and
180 H*). No statistical difference was displayed between G1 and G2 in chroma.
181 Ginger as a spice is used in several different dishes and, as long with its pungent flavour, gives to the
182 product a yellow colour. This peculiarity modified the colour of G2 burgers with higher value of b*
183 (consequently higher values of C* and H*) than G1 and control burgers. These modifications were
184 also detected in other meat products with added plant extracts with a strong intrinsic colour-
185 pigments [34–36]. Changes in colour between control and burgers added with 2% of ginger powder
186 was also confirmed by the ΔE values between the F as function of ST. In regard to storage time L*,
187 b* and C* decreased between D4 and D7 (respectively $P<0.01$, $P<0.05$ and $P<0.05$).
188 Total colour difference (ΔE) values are reported in Table 3 as colour distance between cooked
189 samples of a F at two different time (ST effect) or between samples of different F a specific day of
190 analysis (F effect). Interestingly all the ΔEs calculated as function of the ST within the same F were

lower than the threshold of 2.3 points (threshold limit for a remarkable difference detectable by the human eyes, as proposed by Sharma and Bala [24]); only the C burgers were near to that level (2.29, colour difference between D1 and D7) highlighting a trend to modify their colour over time (even if after 7 days that was not remarkable for the human eyes). On the other hand, as expected, the ΔE between control burgers and the ones containing 2% of ginger were always over the threshold. No discernible colour differences were detected between C and G1 at all the tested storage times. All the ΔEs calculated between the raw and cooked samples showed that all the cooked samples were discernible from their respectively raw samples, as the differences in colour were mainly dependent on cooking and not on ST or the F.

During the storage time colour may change as a consequence of several chemical modifications that occur to meat as depigmentation through oxidation of myoglobin to metmyoglobin [2]. Metmyoglobin is brown in colour and leads to a decrease of lightness of white meat. Burgers presented lowest values of L*, b* and C* at D7 as consequence of modification of the meat and, for the two formulations added with ginger, also a discolouration of ginger pigment may contribute to a decrease of yellowness. The values of ΔE between G1 and G2 also corroborate this hypothesis as ΔE at D1 was higher (and over the recognizable by human) then the differences calculated at D4 and D7. Anyway, these changes in ginger pigments did not affect the total colour differences as no values of ΔE were higher than the threshold of discernibility for the calculation within the same F as function of the ST.

As expected cooking session modified the colour of the burgers, with all the ΔE values over the threshold. Colour modifications occurred in cooking are largely studied and very important in pork meat as colour is commonly used in house cooking to determine when the product is ready to be consumed [37]. Thus, discernible colour differences between raw and cooked samples might be a useful, practical and well accepted characteristic. King and Whyte [37] reported that pH of raw meat could affect colour parameter of cooked meat as it has a significant role in the formation of ferrihemochrome from myoglobin. As pH of raw samples was not statistical different [21] the differences observed in colour indices of cooked samples are likely ascribable to the F. Furthermore, as reported by Andrés-Bello et al. [38], there is a strictly correlation between colour of raw and cooked samples.

Addition of ginger powder strongly influenced fatty acids profile as reported in Table 4, also in this determination no statistical interaction between formulation and storage time was showed. The main saturated fatty acids in burgers were C14:0, C16:0 and C18:0. All these FA were at higher

concentrations in C burgers than G1 and G2 ones; between ginger burgers G2 showed lower values than G1. Total SFA did not show statistical significance between C and G1, anyhow, lower value was showed by G2. All monounsaturated fatty acids were reduced by both concentrations of ginger, without differences between G1 and G2.

Ginger powder increased the contents of both PUFAω3 and PUFAω6 with minor differences between single fatty acids trends. Indeed, as reported by Gur et al. [39] and Zachariah [15] ginger is rich in PUFAs, both of the ω3 and ω6. Total PUFAs and ratio ω3/ω6 were affected by these modifications and showed significant differences between all the F, with lowest values of C, mid values of G1 and higher values of G2. Variations in fatty acids profile affected all the calculated indices with enhanced heathy characteristics in G1 and G2 burgers.

Storage time affected several fatty acids mainly in a progressive way, without strong differences between grade of saturation (Table 4). Two main trends were showed as in one case FAs were reduced day by day (C16:0, C18:0, C18:3ω3, total SFA and total PUFAω3; also, C18:2ω6 and total PUFAω6 partially), and in the other case FAs were drastically decreased at D4 (C16:1, C22:5ω3 and total PUFA). Only C14:0 reported to maintain its percentage between D1 and D4, with a following decrease at D7. As consequences of these reductions the ratio ω3/ω6 was reduced day by day and PI index dropped at D4.

Lipid oxidation (TBARS) and antioxidant capacity (FRAP, ABTS and DPPH) were reported in Table 5. No interaction F x ST was found, never the less for all the analyses both F and ST showed statistically significant differences.

TBARS values of C burgers were higher than the burgers of F G1 and G2 ($P<0.01$), as well as the antioxidant capacity of the control burgers, expressed as ABTS and DPPH, was lower than the burgers added with ginger (both $P<0.001$). No further differences were showed between the addition of 1% or 2% of ginger powder. FRAP evaluation reported an increase in antioxidant capacity in combination with the presence of the spice ($C<G1<G2$, $P<0.001$).

Regarding the ST, lipid oxidation and antioxidant capacity respectively increased and decreased in a gradual way with no differences between D1-D4 and D4-D7 but with a statistical difference only between D1 and D7.

Meat and more likely minced meat could be subject to a rapid deterioration of quality due to enzymatic and microbial degradation [40, 41]. Moreover, lipid oxidation could occur as consequence of several different factors, both endogenous and exogenous. Antioxidant molecules have the peculiarity to stop the chain reaction of oxidation that typically occurs in organic matrix due to free

radicals formation. Ginger, as several other plants, contain a higher number of antioxidant compound such as gingerol, paradol, shogaols, zingerone, zerumbone, terpenoids as well flavonoids and phenols [16, 17]. The addition of ginger powder to the pork meat lead to a lower lipid oxidation and to an increased antioxidant capacity due to the chemical characteristics of ginger. These modifications were also evaluated in raw burgers [21] as well as in other cooked meat products supplemented with plant additives [42–45]. Furthermore, previous studies have shown that ginger powder addiction to pork [21] or beef [46] burgers did not modified the appearance, the aroma and the flavour intensities and seemed to contribute to maintain sensory characteristics during storage time. However, further researches on sensory/consumers liking are suggested.

Principal components analysis (PCA) of the three first PC reached a cumulative percentage of 63.39% of variability (Table 6). Eigenvectors reported in Table 6 and Figure 1 showed that the main factor of variability (PC1) could be ascribed to the addition of ginger, without differentiation between G1 and G2. Indeed, negative values of PC1 represent data linked to the presence of ginger powder, such as b* index (yellowness), antioxidant capacity (FRAP, ABTS and DPPH) and presence of PUFAω3 (C18:3ω3, C20:5ω3, C22:5ω3 and C22:6ω3) and PUFAω6 (C18:2ω6 and C20:4ω6). Positives eigenvectors of MUFA (C14:0, C16:0 and C20:0), as well as TBARS could be more likely associated to the absence of ginger powder and then to the C burger, as revealed also by Figure 1.

A lack of differentiation related to storage time was highlighted as nor PC2 or PC3 described its contribution.

4. Conclusions

Ginger powder increases both nutritional and functional properties of pork burgers. Antioxidant compounds, naturally contained in ginger, increased the capacity of the burgers to resist to lipid oxidation during 7 day of refrigerated storage. Moreover, adding 2% ginger powder as ingredient in the formulation of the burgers induced a reduction of the total SFA with increased healthy values of these ready to cook products.

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411 their application to ground beef patties. Food Chem 69:135–141 . doi: 10.1016/S0308-
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413

414 Table 1. Proximate composition, antioxidant capacity, colour and fatty acids profile of ginger

415 powder.

Proximate composition (%)	
Moisture	6.47
Fat	6.51
Protein	13.80
Ash	8.02
Antioxidant capacity	
ABTS	118.34
DPPH	10.99
FRAP	75.51
Colour	
L*	73.04
a*	5.08
b*	30.50

Fatty acids profile (%)	
C16:0	20.49
C18:0	10.08
SFA	37.52
C18:1	15.85
MUFA	21.23
C18.3ω3	2.90
C22:5ω3	2.02
PUFAω3	7.90
C18.2ω6	27.35
C20:2ω6	2.03
C22:2ω6	2.00
PUFAω6	33.35
PUFA	41.25

ABTS and DPPH in mmol of Trolox equivalent per kilogram of ginger powder; FRAP in mmol of Fe^{II} equivalent per kilogram of ginger powder.

Also C14:0, C15:0, C17:0, C20:0, C22:0, C24:0, C14:1, C16:1, C17:1, C22:1, C20:5ω3, C22:6ω3, C18:3ω6 and C20:4ω6 were detected in lower amounts. All the mentioned fatty acids have been utilized for calculating sum of lipid fractions.

416

417 Table 2. pH and colour parameters of burgers in relation to the formulation and the storage time.

	Formulation (F)			Storage time (ST)			P-value		RMSE
	C	G1	G2	D1	D4	D7	F	ST	
N	9	9	9	9	9	9			
pH	6.20	6.31	6.23	6.26	6.29	6.19	0.885	0.905	0.475
L*	26.81	26.94	26.52	26.72^{xy}	27.37^{x}	26.17^{y}	0.461	0.008	0.723
a*	12.92	12.85	11.99	13.25	12.08	12.43	0.155	0.087	1.076
b*	15.29^{b}	16.39^{b}	17.90^{a}	16.60^{xy}	17.17^{x}	15.80^{y}	<0.001	0.020	0.929
C*	20.03^{b}	20.84^{ab}	21.59^{a}	21.30^{x}	21.04^{x}	20.13^{y}	0.005	0.029	0.877
H*	49.83^{b}	51.94^{b}	56.16^{a}	51.03	54.83	51.79	0.001	0.054	2.975

C: cooked burgers of only meat; G1: cooked burgers of meat added with 1% (w/w) of ginger powder; G2: cooked burgers of meat added with 2% (w/w) of ginger powder.

$^{a, b}$ In the same row indicate significant differences for F.

$^{x, y}$ In the same row indicate significant differences for ST.

418

419 Table 3. Total colour difference (ΔE) of burgers as function of the storage time or the formulation
420 and between raw and cooked samples with fixed time and formulation.

	ΔE Storage time (ST)		
Formulation (F)	D1–D4	D4–D7	D1–D7
C	1.58	1.68	2.29
G1	1.77	1.69	0.49
G2	1.13	1.55	1.33

	ΔE Formulation (F)		
Storage time (ST)	C–G1	C–G2	G1–G2
D1	1.12	3.37*	2.28
D4	1.07	2.51*	1.45
D7	1.97	2.74*	1.72

Raw-Cooked

	Storage time (ST)		
Formulation (F)	D1	D4	D7
C	5.24*	7.30*	5.33*
G1	4.64*	5.93*	4.20*
G2	3.93*	4.93*	3.31*

C: cooked burgers of only meat; G1: cooked burgers of meat added with 1% (w/w) of ginger powder; G2: cooked burgers of meat added with 2% (w/w) of ginger powder.

*Value over the threshold (2.3 points) with a noticeable difference in colour between the samples.

421

422 Table 4. Fatty acids profile (% of total FAME) and correlated indices of burgers.

Fatty acids	Formulation (F)			Storage Time (ST)			P-value		RMSE
	C	G1	G2	D1	D4	D7	F	ST	
N	9	9	9	9	9	9			
C14:0	1.93^{a}	1.72^{b}	1.20^{c}	1.66^{x}	1.68^{x}	1.51^{y}	<0.001	<0.001	0.098
C16:0	22.99^{a}	22.91^{b}	21.94^{c}	22.87^{x}	22.61^{y}	22.35^{z}	<0.001	<0.001	0.040
C18:0	13.46^{a}	13.29^{b}	12.95^{c}	13.73^{x}	13.13^{y}	12.85^{z}	<0.001	<0.001	0.037
SFA	*39.48^{a}*	*38.93^{a}*	*37.45^{b}*	*39.64^{x}*	*38.42^{y}*	*37.80^{z}*	*<0.001*	*<0.001*	*0.514*
C16:1	2.21^{a}	2.10^{b}	2.09^{b}	2.18^{x}	2.14a^{y}	2.09^{y}	<0.001	0.0041	0.047
C18:1ω9	38.67^{a}	37.87^{b}	37.94^{b}	38.07	38.16	38.26	<0.001	0.546	0.047
C20:1	0.71^{a}	0.65^{b}	0.67^{b}	0.69	0.68	0.66	0.019	0.205	0.036
MUFA	*42.36^{a}*	*41.49^{b}*	*41.70^{b}*	*41.87*	*41.85*	*41.81*	*<0.001*	*0.911*	*0.269*
C18:3ω3	1.29^{c}	1.41^{b}	1.84^{a}	1.68^{x}	1.52^{y}	1.34^{z}	<0.001	<0.001	0.039
C22:5ω3	0.17^{b}	0.62^{a}	0.54^{a}	0.53^{x}	0.41^{y}	0.39^{y}	<0.001	0.003	0.077
C22:6ω3	0.53^{b}	0.51^{b}	0.86^{a}	0.67	0.62	0.61	<0.001	0.187	0.078
PUFAω3	*2.03^{c}*	*2.60^{b}*	*3.29^{a}*	*2.93^{x}*	*2.59^{y}*	*2.39^{z}*	*<0.001*	*<0.001*	*0.132*
C18:2ω6	14.99^{c}	16.35^{b}	16.69^{a}	16.04^{x}	16.02^{xy}	15.98^{y}	<0.001	0.014	0.041
C20:4ω6	0.98^{c}	1.53^{b}	1.72^{a}	1.43	1.40	1.40	<0.001	0.108	0.032
PUFAω6	*16.68^{c}*	*18.87^{a}*	*18.95^{a}*	*18.27^{x}*	*18.17^{xy}*	*18.06^{y}*	*<0.001*	*0.044*	*0.165*
PUFA	*18.72^{c}*	*21.47^{b}*	*22.24^{a}*	*21.20^{x}*	*20.76^{y}*	*20.46^{y}*	*<0.001*	*<0.001*	*0.266*
AI	*0.49^{a}*	*0.47^{a}*	*0.42^{b}*	*0.47*	*0.45*	*0.46*	*<0.001*	*0.461*	*0.025*
TI	*1.07^{a}*	*0.99^{b}*	*0.90^{c}*	*0.99*	*0.98*	*0.99*	*<0.001*	*0.893*	*0.141*
h/H	*2.31^{c}*	*2.36^{b}*	*2.57^{a}*	*2.39*	*2.42*	*2.43*	*<0.001*	*0.144*	*0.037*
PI	*29.14^{c}*	*35.78^{b}*	*39.64^{a}*	*36.19^{x}*	*34.50^{y}*	*33.87^{y}*	*<0.001*	*<0.001*	*0.957*
ω3/ω6	*0.12^{c}*	*1.14^{b}*	*0.17^{a}*	*0.16^{x}*	*0.14^{y}*	*0.13^{z}*	*<0.001*	*<0.001*	*0.006*

C: cooked burgers of only meat; G1: cooked burgers of meat added with 1% (w/w) of ginger powder; G2: cooked burgers of meat added with 2% (w/w) of ginger powder.

C15:0, C17:0, C20:0, C22:0, C24:0, C14:1, C15:1, C17:1, C22:1ω9, C24:1, C18:3ω6, C20:5ω3, C20:2ω6, C22:2ω6 were detected but not summarized because found below 1% of total FAME. All the mentioned fatty acids have been utilized for calculating sum of lipid fraction.

AI: Atherogenicity index; TI: Thrombogenicity index; h/H: hypocholesterolemic index/Hypercholesterolemic index; PI: Peroxidisability index.

[a, b, C] In the same row indicate significant differences for F.

[x, y, Z] In the same row indicate significant differences for ST.

423

424 Table 5. Lipid peroxidation (TBARS) and antioxidant capacity of burgers (FRAP, ABTS and DPPH).

	Formulation (F)			Storage time (ST)			P-value		RMSE
	C	G1	G2	D1	D4	D7	F	ST	
N	9	9	9	9	9	9			
TBARS	0.10^{a}	0.07^{b}	0.07^{b}	0.07^{y}	0.08^{xy}	0.10^{x}	0.007	0.030	0.020
FRAP	0.24^{c}	1.50^{b}	2.62^{a}	1.63^{x}	1.44^{xy}	1.29^{y}	<0.001	0.029	0.244
ABTS	1.50^{b}	2.53^{a}	2.63^{a}	2.49^{x}	2.23^{xy}	1.94^{y}	<0.001	0.018	0.369
DPPH	0.11^{b}	0.14^{a}	0.14^{a}	0.14^{x}	0.13^{xy}	0.12^{y}	<0.001	0.031	0.013

C: cooked burgers of only meat; G1: cooked burgers of meat added with 1% (w/w) of ginger powder; G2: cooked burgers of meat added with 2% (w/w) of ginger powder.

TBARS expressed in mg of MDA-eq. per kilogram of fresh meat; ABTS and DPPH in mmol of Trolox equivalent per kilogram of fresh meat; FRAP in mmol of Fe^{II} equivalent per kilogram of fresh meat.

$^{a, b, c}$ In the same row indicate significant differences for F.

$^{x, y}$ In the same row indicate significant differences for ST.

425

Table 6. Eigenvalues and eigenvectors of the first three principal components (PC) of principal components analysis conducted on the physical-chemical characteristics (pH, L*, a*, b*), single fatty acids, lipid oxidation (TBARS) and antioxidant capacity (FRAP, ABTS and DPPH) of burgers stored up to 7 days.

	PC		
	PC 1	PC 2	PC 3
Eigenvalues	11.5377	5.4846	3.8962
Eigenvectors			
L*	0.0108	0.1002	-0.1883
a*	0.0732	0.1182	-0.2153
b*	-0.2235	-0.0076	0.0430
pH	-0.0450	0.1156	-0.1067
TBARS	0.1802	0.0744	0.1751
FRAP	-0.2775	-0.0194	0.0218
ABTS	-0.2419	0.0259	-0.2036
DPPH	-0.2128	-0.0146	-0.1439
C14:0	0.2343	0.0343	-0.1904
C15:0	-0.2070	0.1375	0.2169
C16:0	0.1868	0.0072	-0.3147
C17:0	0.0044	0.3410	0.1172
C18:0	0.0486	0.0546	-0.1207
C20.0	0.1992	0.2668	0.0987
C22:0	-0.1614	0.2843	-0.1130
C24:0	-0.1378	0.2653	-0.1295
C14:1	-0.0683	0.2842	0.1084
C15:1	-0.2222	0.1369	0.0972
C16:1	0.1329	0.1759	-0.0657
C17:1	0.1817	0.2884	-0.0037
C18:1ω9	0.1392	-0.0409	0.2587
C20:1	0.0722	0.3478	-0.0800
C22:1ω9	-0.1253	0.0545	-0.2846
C24:1	-0.2688	0.0452	-0.0283

C18.3ω3	-0.2531	0.0633	0.1390
C20:5ω3	-0.0507	0.1631	-0.0364
C22:5ω3	-0.2295	-0.1152	-0.2062
C22:6ω3	-0.2156	0.0756	0.2474
C18.2ω6	-0.2074	0.0047	-0.1699
C18:3ω6	-0.0554	0.3628	-0.0279
C20:2ω6	0.1032	0.2316	-0.1567
C20:4ω6	-0.2575	-0.0566	-0.0973
C22:2ω6	0.0599	-0.1215	-0.4394
Cumulative %	34.96	51.58	63.39

430

Figure 1. Biplot (Loading and Score plots) of the principal component analysis (PCA) performed on the physical-chemical characteristics (pH, L*, a*, b*), single fatty acids, lipid oxidation (TBARS) and antioxidant capacity (FRAP, ABTS and DPPH).

Figure Captions

Fig 1

C: cooked burgers of only meat; G1: cooked burgers of meat added with 1% (w/w) of ginger powder; G2: cooked burgers of meat added with 2% (w/w) of ginger powder. Storage time as D1, D4 and D7, respectively for day 1, 4 and 7.