Effect of different format-solvent rosemary extracts (Rosmarinus officinalis) on frozen chicken nuggets quality

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A B S T R A C T

Three kinds of Rosmarinus officinalis extract (powder-acetone, liquid-methanol, liquid-acetone) were used to examine the effects of format-solvent on the active compounds extracted (total phenolic, carnosol and carnosic acid content) and antioxidant activity (FRAP, ABTS). The results showed that both, as the format but also the solvent used, had significant effect on the parameters analyzed (p < 0.05). The highest antioxidant activity was found for the powder-acetone extract followed by the liquid methanol and liquid acetone extracts (p < 0.05). The effect of the three different extracts on the physical–chemical and sensory quality of frozen chicken nuggets was evaluated. At the dose proposed by the European Union Directive 2010/69/EU for the carnosic and carnosol compounds [150 ppm (mg/kg fat basic)], the format-solvent combination of the rosemary extracts used did not modify the chicken nuggets quality characteristics (pH, colour, sensory quality) and still underlines the effectiveness of these extracts.

1. Introduction

Chicken-based foodstuffs are becoming increasingly popular mainly as “ready-to-eat” products, such as frozen chicken nuggets, because of the reduced preparation time, their good nutritional quality as a protein source and the low cost and longer shelf-life in frozen conditions (Magdelaine, Spiess, & Valceschini, 2008). The high polyunsaturated fatty acid profile of chicken meat, while nutritionally interesting, makes the product very susceptible to oxidative reactions, which may be intensified by deep-frying, the usual preparation way of this product. Moreover, these lipid oxidation reactions, which are considered the major deterioration form in stored muscle foods, may still occur during frozen storage (Soyer, Özalp, Dalmış, & Bilgin, 2010). Such changes could affect the physical–chemicals parameters and sensory attributes (odour, colour, and flavour) of the product, in addition to diminish the shelf-life (Selani et al., 2011).

Synthetic antioxidants have been successfully used to prevent lipid oxidation in chicken meat. However, increasing concerns over the safety of synthetic food additives have resulted in a trend towards “natural products”. As a result, the industry faces a challenge to find effective antioxidants from natural sources to prevent deterioration in meat and meat products during processing and storage (Brannan, 2009). Among natural antioxidant sources, rosemary (Rosmarinus officinalis L.), a woody aromatic herb that is native to the Mediterranean countries, has recently been authorized by the European Union under Directive 95/2/EC and assigned E-392 as its E number (European Union Directives 2010/67/EU and 2010/69/EU) for use in meat product preservation. The addition of rosemary extract to poultry products has been shown to be effective in retarding lipid oxidation, and previous studies in chicken sausages (Liu, Tsau, Lin, Jan, & Tan, 2009) and patties (Naveena et al., 2013) have pointed to the protective effect of rosemary extract (500–1500 ppm) and leaves (22.5–130 ppm) in inhibiting lipid oxidation.

Rosemary antioxidant activity is related to components such as phenolic diterpenes, carnosol (CAS No. 5957-80-2) and carnosic acid (CAS No. 3650-09-7) (Rodriguez-Rojo, Visentin, Maestri, & Cocero, 2012). The antioxidant capacity of phenolic compounds is due to their ability to scavenge free radicals, donate hydrogen atoms and chelate metal cations (Shan, Cai, Sun, & Corke, 2005). Previous studies (Azmir et al., 2013; Wang, Wang, & Li, 2013) have reported that the yield of bioactive compounds can be changed or
modified by using different extraction procedures, solvents, temperatures, pressures and times. In an earlier paper (Garrido, Auqui, Martí, & Linares, 2011) extraction systems to obtain red grape pomace extracts were studied, and the extraction process was seen to have a clear effect on the extract composition (antioxidant activity, total polyphenols and total anthocyanins) and on the inhibition of lipid oxidation in pork burgers.

Therefore, the aims of this study were (1) to characterize three different commercial rosemary extracts (R. officinalis) obtained in different ways (format-solvent combinations) and (2) to evaluate the effect of these rosemary extracts on the physical-chemical and sensory quality of frozen chicken nuggets during 9 months of storage.

2. Material and methods

2.1. Characterization of rosemary extracts

The rosemary extracts used in this study were elaborated by Natural Ingredients S.L. (Ingrenat S.L., Cartagena, Spain). The extracts were obtained from rosemary leaves by “Liquid–Solid Extraction” with methanol or acetone as principal extract and solvents. Both solvents are usually used for phenolic diterpene extraction due to their hydrogen-bonding ability that provides a high antioxidant yield (Erkan, Ayarnci, & Ayarnci, 2008). Both extraction processes (with acetone or methanol) were optimized by the company to improve the purity and deodorization of the extract, and are currently under patent. Two format types were considered: liquid and powders. Finally, the company obtained three types of extracts:

- Powder-acetone: powdered rosemary extract obtained using acetone as solvent.
- Liquid-methanol: liquid rosemary oil extract obtained using methanol as solvent.
- Liquid-acetone: liquid rosemary oil extract obtained using acetone as solvent.

2.1.1. Concentration of carnosic acid and carnosol

Carnosol and carnosic acid were identified and quantified in the extract samples using high performance liquid chromatography (HPLC), as described by Okamura, Fujimoto, Kuwabara, and Yagi (1994). Extract samples were dissolved in acetone (1:10, w/v), and insoluble substances were removed by ultrasonic stirring and filtration through a 0.45 μm nylon mesh. The analysis was performed with an Agilent 1200 series HPLC instrument (Agilent Technologies, Waldbronn, Germany) equipped with an autosampler. The column was a HiChrom Hi-RPB 18 type with 250 mm with a 5 μm particle size diameter (Hichrom Ltd, Reading, United Kingdom). The mobile phase consisted of acetonitrile (H) and purified water containing 1% acetic acid HPLC (B) applying the following gradient: 0–10 min 30% A, 70% B; 10–22.5 min 65% A, 35% B; 22.5–27.6 min 100% A, 0% B; 27.6 min 30% A, 70% B; stop 30 min. The flow rate was constant at 1.2 ml/min. The detector was equipped with a diode array detector (DAD) operating at 284 nm based on the standard solutions of carnosol and carnosic acid.

2.1.2. Antioxidant capacity

2.1.2.1. Total phenolic content. The total phenolic content (TPC) was determined by the Folin–Ciocalteu colorimetric technique (Rodríguez-Carpena, Morcuende, Andrade, Kylli, & Estevez, 2011).

2.1.2.2. Ferric reducing antioxidant power assay (FRAP). The total antioxidant capacity of the different extracts was determined using the ferric reducing antioxidant power (FRAP) assay by the method of Benzie and Strain (1996) with some modifications.

2.1.2.3. ABTS+ radical cation assay. Radical cation scavenging capacity was measured for the extract against ABTS + generated as described by Rodríguez-Carpena et al. (2011).

2.2. Chicken nuggets

2.2.1. Sample formulation, preparation and storage conditions

The nuggets were experimentally manufactured following commercial practices for pre-fried products. For this purpose deboned skinless chicken breasts (60%) were minced with ice (23%) in a chopper for 30 s. The usual additives for commercial nuggets, 15% potato flakes (McCain alimentaríe S.A.S., Harnes, France); 1% salt (Salinas del Odiel S.L., Huelva, Spain) and 1% albumin (Huevos Guillén S.L., Valencia, España) were used. All components were thoroughly mixed to provide an uniform blend, and the chicken nugget samples were prepared in characteristic shapes of 5 × 3 × 1 cm, each weighing 25 g, and frozen at ~18 °C. The pieces were dipped in the prepared batter (wheat flour 93.57%, salt 1.17% bicarbonate 0.24%, yeast 2.34% and xanthan gum 1.17%) for 15 s. Chicken nuggets were distributed into five different batches according to the following formulas: a control batch without any extract (1) and a batch with tocopherol extract (2) were used to check the rosemary extract effect. Tocopherol was selected because it is a commonly antioxidant used in food matrices (McCarthy, Kerry, Lynch, & Buckley, 2001). The doses of the three different rosemary extracts were selected to ensure 150 ppm of carnosic and carnosol expressed as fat basic in products according to European Union Directive 2010/69/EU on food additives. Given the differences in the composition and antioxidant capacity of the three of extracts, the following doses were used: reaches to 150 ppm carnosic acid and carnosol: 600 ppm powdered-acetone (3), 900 ppm liquid-methanol (4) and 300 ppm liquid-acetone and liquid-tocopherol (5).

All the nugget batches were pre fried using a household fryer (Taurus S.L., Lérida, Spain) for 30 s at 165 °C in sunflower oil (Sove-na España S.A., Sevilla, Spain). The pre-fried nuggets were then packaged in polyethylene bags and stored at ~18 °C for 9 months. Physical-chemical (lipid oxidation, colour and pH) and sensory analysis were carried out in the samples after 0, 3, 6 and 9 month. Physical-chemical (Lipid oxidation, colour and pH) and sensory analyze were carried out in the samples after 0, 3, 6 and 9 month. A total of 480 chicken nuggets were used, 200 for the physical-chemical analysis (5 nuggets * 5 batch * 4 time) by duplicated and 280 for the sensorial analysis (7 nuggets * 5 batch * 4 time) by duplicated.

2.2.2. Lipid oxidation

Thiobarbituric acid reactive substances (TBARS) were measured according to the method of Targladis, Watts, Younathan, and Duggan (1960). The analysis was repeated by triplicate.

2.2.3. Colour coordinates (L*, a*, b*)

Colour was measured using a Minolta CR400 colorimeter standardized using a white calibration plate (Minolta Camera Co., Osaka, Japan) (8-mm-diameter aperture, d/0 illumination system, D65 illuminant and a 2° standard observer angle) by triplicate. Lightness (L*), green–red chromacity (a*) and blue–yellow chromacity (b*) were measured according to the CIELab system.

2.2.4. pH measurement

The pH of the nugget samples was measured by triplicate using Crison GLP21 equipment (Crison Instruments S.A., Barcelona, Spain) (ISO 2917:1999).
2.2.5. Sensory analyses: qualitative descriptive analysis (QDA)

For the sensory analysis, all evaluations were conducted in individual booths which contained the instructions for the evaluation procedure. The tasting room for sensory evaluation was air-conditioned and free of disturbing factors. The pre-fried nuggets samples were fried in a household deep fat fryer (Taurus S.L., Lérida, Spain) at 165 °C for 5 min, until reaching an internal temperature of 72 °C, as measured by a portable T200 thermometer (Digitron Instrumentation Ltd., Hertford, United Kingdom). Rectangular pieces of approximately 2 x 1.5 cm were obtained and immediately presented to the panelists.

The panelists were trained according to ISO 8586 (2012). Seven training sessions were carried out: in the three first, descriptors of chicken nuggets were studied and the following four sessions were concerned with identifying, selecting and quantifying attributes to evaluate the nuggets. In training and panel performance sessions, samples were coded with random three digit numbers and were presented individually to the panelists (Macfie, Bratchell, Greenhoff, & Vallis, 1989). Mineral water was provided for mouth rinsing between samples. Sensory analysis was carried out using an unstructured scale of 10 cm. The textural parameters analyzed were crispness, juiciness, firmness, and cohesiveness. For the colour, odour and taste characteristics the following attributes were considered: odour intensity, rancid odour, crust colour, mass colour, taste intensity, rancid taste. The sensory test was repeated by triplicate.

2.3. Statistical analysis

Data were analyzed with the statistical package SPSS 15.0 (Statistical Package for the Social Science for Window) (IBM, Armonk, New York, USA). The effect of the different type of extract on chicken nuggets quality was analyzed using ANOVA. When the differences among batches were significant (p < 0.05), Tukey’s test at a significance level of p < 0.05 was applied out to test differences between groups.

3. Result and discussion

3.1. Characterization of rosemary extracts

3.1.1. Composition of rosemary extract and antioxidant capacity

Table 1 shows the composition (total phenolics content, carnosic acid, carnosol, and essential oil content) of the rosemary extracts (powder acetone, liquid acetone, and liquid rosemary). Phenolic compounds constitute the main type of secondary metabolite with antioxidant activity in plant and herbs (Shan et al., 2005). In rosemary extracts, carnosic acid and its derivatives, carnosol, rosmadial, rosmanol isomers and methyl carnosate are the main compounds involved in such activity (Naveena et al., 2013). The results showed that the phenolic contents varied considerably (from 18.62 to 23.23 g GAE/100 g extract) as a function of the solvent and the format type, a finding similar to that found by Dorman, Peltoketo, Hiltunen, and Tikkanen (2003) for de-odourised aqueous rosemary extract. Shan et al. (2005) studied the total phenolic constituents of 26 spice extracts and found the value of 5.07 g GAE/100gr for the methanol extract of rosemary, which is lower than the results the present study. In contrast, Han and Rhee (2005) found higher values (30.4 g GAE/100 g) for the total phenolic content in rosemary dry powder extract than those found in the current research, probably because their extract was not subjected to deodorizing and bleaching processes. Previously, Sundram and Gapor (1994) observed that refined, bleached and deodorized process in oil, olein and stearin palm showed a partial loss (around 25%) of one of its mainly antioxidant, vitamin E. The phenolic content was higher in the powder acetone extract (23.23 g GAE/100 g) than in the two liquid extracts. It seems that the dissolution process carried out to obtain the liquid extracts decreases the phenolic compound content. As regards the liquid extracts, the results revealed that liquid methanol obtained higher values than liquid acetone. Acetone and methanol have been extensively used as solvents for the extraction of phenolic compounds due to these compounds are distributed in low-to mid-polar extract (Trabelsi et al., 2010; Wang et al., 2013; Zhao et al., 2006). However, the yield in the liquid extraction process mainly depends on the solvents chosen, probably due to the polarities involved and therefore to the capacity to solubilize chemical constituents of the samples (Azmir et al., 2013). In disagreement, Wang et al. (2013) studied the effect of different polarity solvents on the extraction of phenolic compounds of various extracts of Malus baccata L. and obtained a major yield in samples extracted with 80% acetone, ethanol, ethyl acetate and distilled water, respectively. Zhao et al. (2006) also found that the acetone extract contained the highest amount of phenolic compounds followed by ethanol, methanol and water extract in barley (Hordeum vulgare L.). The results of the present study could be explained by the extraction of other chemical constituents in rosemary leaves such as essential oils, which would be included in the final extract. Rosemary essential oil includes compounds such as p-cimeno, linalool, gamma-terpineno, timol, beta-pineno, alpha-pineno, and eucalyptol, monoterpen hydrocarbons with a low molecular weight, high vapour pressure and low polarity (Da Cruz Francisco & Simik, 2002), which have more affinity for the acetone solvent, that interfering in phenolic compounds extraction. This is evident in the essential oil values obtained: liquid acetone extract is approximately 4 times more concentrated than liquid methanol extract (197.27 vs. 943 mg/kg extract). The results obtained for carnosic acid and carnosol concentration are in accordance those obtained for the measurement of total phenolics.

The powder rosemary extract was the most concentrated of active compounds and antioxidant capacity measured by FRAP

Table 1

<table>
<thead>
<tr>
<th>Composition</th>
<th>Type of extract</th>
<th>Liquid acetone</th>
<th>Liquid methanol</th>
</tr>
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<tbody>
<tr>
<td>Total phenolics (mg GAE/100 g extract)</td>
<td>23.23 ± 0.39&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.62 ± 0.55&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20.41 ± 0.20&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Carnosic acid (g/kg)</td>
<td>179.16 ± 0.14&lt;sup&gt;a&lt;/sup&gt;</td>
<td>46.53 ± 0.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>67.44 ± 0.74&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Carnosol (g/kg)</td>
<td>28.88 ± 0.76&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.84 ± 0.17&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.57 ± 0.06&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Essential oil (mg/kg)</td>
<td>1052.00 ± 39.68&lt;sup&gt;c&lt;/sup&gt;</td>
<td>943.00 ± 50.21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>197.27 ± 8.00&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Antioxidant activity&lt;sup&gt;ab&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>FRAP (μM/g)</td>
<td>2063.82 ± 7.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>660.31 ± 4.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1186.54 ± 3.91&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>ABTS&lt;sup&gt;+&lt;/sup&gt; (nM Trolox/g)</td>
<td>1043.47 ± 12.85&lt;sup&gt;c&lt;/sup&gt;</td>
<td>247.30 ± 2.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>811.66 ± 17.12&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
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</table>

<sup>a</sup> All data are expressed as mean value ± standard deviation (n = 3).
<sup>b</sup> Means with different letters (a, b) within the same column are significantly different (p < 0.05).
and ABTS analysis. Some authors like Erkan et al. (2008) found that rosemary extract was a more powerful antioxidant than blackseed essential oil due to its higher phenolic content. Wang et al. (2013) studied the effect of solvent in M. baccata L. extracts and described a higher antioxidant activity in the extract containing the higher concentration of phenolic compounds. Amarowicz, Pegg, Rahimi-Moghaddam, Barl, and Weil (2004) observed a direct relation between the antioxidant activity and reducing power of certain plant extracts, which have been shown to exert an antioxidant action by breaking the free radical chain through the donation of hydrogen atom. The antioxidant activity mechanism of rosemary extracts is similar to that of other polyphenol and flavonoids. The presence of a catechol group in the aromatic ring (C11–C12) of the rosemary phenolic diterpene skeleton is probably the most important structural element in the antioxidant activity of these compounds (Shan et al., 2005). Therefore, the extracts containing more phenolic compounds, in particular carnosic acid and carnosol, prevent the formation of reactive radical species and produce a higher antioxidant effect. As can be viewed in the Table, the extract with more phenolic compounds is powder acetone extract (23.23 mg GAE/100 g extract) which also has higher antioxidant activity, followed by liquid methanol extract (20.41 mg GAE/100 g extract) and liquid acetone extract (18.62 mg GAE/100 g extract).

3.2. Quality evaluation of chicken nuggets

3.2.1. Lipid oxidation

Fig. 1 shows the TBARS (mg malondialdehyde/kg sample) values of the different chicken nugget batches stored at –18 °C. The values varied between 4.07 and 5.88 mg malondialdehyde/kg during the 9 months storage period. These results agree with those obtained by Wang, Day, and Chen (1976) in a study that evaluated frozen commercial fried chicken products, in which TBARS values ranged between 2.1 and 9.2 mg malondialdehyde/kg sample. The control group (no antioxidant) showed significantly higher (p < 0.05) lipid oxidation values associated with the storage time at 9 months. In the same way, Modi, Mahendrakar, Sachindra, and Narasimha Rao (2004) reported increases in TBARS values during frozen storage (6 months) of chicken nuggets. However, the batches formulated with antioxidant (powder-acetone, liquid-methanol, liquid-acetone, and liquid-tocopherol) maintained constant TBARS values (p > 0.05). A similar trend was observed by Modi, Sachindra, Sathisha, Mahendrakar, and Narasimha rao (2006) in chicken curry during 6 months of frozen storage, behaviour that they associated with the effect of both the low temperatures and the antioxidant capacity of the spices added. The differences between the treatment groups were not statistically significant, probably because freezing made it difficult to detect a clear deterioration of the product. The effectiveness of rosemary as an inhibitor of lipid oxidation in meat products has been documented so, some authors (Naveena et al., 2013) evaluated the effect of carnosic acid extracted from dried rosemary leaves in cooked chicken patties during refrigerated storage and observed a reduction of TBARS from 37% to 87% compared with the control group. Others (Hwang et al., 2013) showed an increase in the shelf life of raw and deep fried chicken nuggets containing other natural antioxidants (Artemisia princeps Pamp and ascorbic acid) whose polyphenolic constituents inhibited lipid oxidation.

3.2.2. pH and colour

The pH and colour measurements of nuggets during the 9 months of frozen storage period are presented in Table 2. The initial pH values were similar to those found in previous studies in refrigerated chicken nuggets (6.35) (Kumar, Kumar Biswas, Kumar Chatli, & Sahoo, 2011). Neither tocopherol nor rosemary extract significantly affected pH of the chicken nuggets (p > 0.05). Modi, Sachindra, Sathisha, Mahendrakar, and Narasimha Rao (2006) also did not find significant differences in pH during a storage period of 6 months in curry chicken, while Naveena et al. (2013) found no effect of rosemary addition or storage on pH in buffalo and chicken patties. Selani et al. (2011) and Mohamed and Mansour (2012) neither showed changes due to the addition natural extracts or frozen storage in cooked chicken meat and beef patties, respectively.

As respect the colour coordinates, no significant effect (p > 0.05) of storage time was evident in any of the nugget groups. Selani et al. (2011) observed similar results in cooked chicken meat stored frozen in similar time (9 months). Machado-Velasco and Vélez-Ruiz (2008) studied the physical properties of different types of Mexican foodstuffs, including cereal-based foods similar to nugget crusts, during frozen storage, finding no alterations after two months storage. In contrast, others like Giannou, Tzia and LeBail (2005) and Kindt, Mazzaracchio, and Barbiroli (2008) observed an increase in crust colour during the frozen storage of a mass-fried-bakery product (dough) and pasta, which was attributed to the formation of white ice spots on the crust surface. However, even after 9 months of frozen storage, the samples remained fairly acceptable from a commercial point of view. As regards the impact of treatment, there were no significant differences (p > 0.05)
between treatments and the control samples in L* and b* values. However, a significant effect (p < 0.05) was observed with regard to a* values, although this trend did not follow a consistent evolution, probably due to the small differences resulting from the “homemade” production process more than to the effect of extracts themselves. Accordingly, this result realized that the colour of the extracts has not interfered with the characteristic batter colour and therefore the doses used can be commercially applied in future. Other natural antioxidants have been seen to interfere colour and therefore the doses used can be commercially applied in future (Ganhão, Morcuende & Estevez, 2010; Selani et al., 2011).

3.2.3. Sensory evaluation

Tables 3 and 4 show the sensory analysis results for the five treatment groups (control, powder-acetone, liquid-methanol, liquid-acetone, and liquid-tocopherol) after frozen storage for 0, 3, 6, and 9 months.

The texture attributes (crispness, juiciness, firmness, and cohesiveness) (Table 3) showed no clear treatment-related trends. In agreement, Mohamed and Mansour (2012) did not detect significant changes in juiciness, firmness and cohesiveness scores in beef patties with added antioxidant extracts (rosemary and majoran). Significant differences (p < 0.05) were found in crispness and juiciness due to frozen storage, possibly associated with the ice crystals produced by the frozen process that may damage the tissues and result in drip losses during thawing (Totosausa & Kerry, 2012).

The use of natural extracts (rosemary and tocopherol) did not affect mass or crust colour, odour intensity or taste intensity (Table 4). The results of the sensory evaluation are similar to those described with the instrumental evaluation (Table 2), in which colour did not vary between treatments or between sampling times.
(0, 3, 6, and 9 months). Naveena et al. (2013) described lower colour and higher off-odour scores in raw and cooked ground buffalo meat patties and chicken patties containing unrefined rosemary extract (22.5–130 ppm), when was used refined oleoresins extract (22.5–130 ppm), when was used refined oleoresins.

Regarding effect of frozen storage (9 months), the attributes crust colour and mass colour were unaffected. A similar result was found Selani et al. (2011) in cooked chicken meat with respect frozen storage (9 months). In general, the odour and taste intensity scores gradually decreased (p < 0.05) during the 9 months of frozen storage compared with initial values (Table 4), although scores were still high (8.90–9.41). A decrease in sensory scores with time

4. Conclusion

The format and solvent types used in the present study influenced the amount of phenolic compounds in the rosemary extracts obtained and therefore in their antioxidant capacity. After characterizing of the different extracts, it can be concluded that the powder acetone had the higher antioxidant potential followed by liquid methanol and liquid acetone.

The addition of these rosemary extracts to chicken nuggets had no affect on the physical–chemical characteristics (colour, pH) and sensory quality of the product, that pointed out to their potential use as alternatives in the production of pre-fried products. After 9 months of storage, a slight tendency as regarding the effectiveness of these natural extracts as antioxidant compounds was observed, but possibly a longer storage would be required to confirm this subject.
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