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14 Use of biodegradable materials as alternative packaging of typical Calabrian Provola cheese

15

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30

31 Abstract

32 Calabrian Provola cheese is typically manufactured in the Southern Italy. The request of a more

33 suitable expansion in the national market has promoted this research, based on the evaluation of

34 biodegradable packaging on its qualitative characteristics as alternative of the conventional plastic

35 multilayer film. The tested materials were: Polyethylene/Ethylene vinyl

36 alcohol/Polyamide/Polyethylene (PE/EVOH/PA/PE), Polylactic acid (PLA), coated with a silicon

37 oxide barrier, and Cellophane, coated with resins. The results of this study evidenced that the material

38 based on PLA can be considered a valid alternative packaging because of the quality maintenance of

39 Calabrian Provola cheese and its sustainable characteristics.

40

41 Key words: Biodegradable materials, Calabrian Provola cheese, Cellophane, Packaging, Polylactic
42 acid

43 1. Introduction

44 The dairy industry is the first food product sector in Italy. The cheese production has increased in the
45 last decade and today it counts more than one millions of tons with a growth in the export, so much
46 so one of three cheeses produced in Italy is sold abroad (Eurostat, 2015). About 48 Italian cheeses
47 possess the Protected Denomination of Origin (PDO) and, in addition, the Calabrian Provola cheese
48 has received the quality denomination of PAT (Prodotto Agroalimentare Tipico - Typical Food and
49 Agricultural Product) by the Ministry of Agricultural, Food and Forestry Politics among other typical
50 food products (Official Gazette of the Italian Republic, 2014). The Provola is a ‘pasta filata cheese’,
51 generally cow’s milk-based, characterized by a stretched curd, and a compact and smooth rind. Its
52 colour varies from bright white to light yellow, influenced by the length of ripening. It owes the name
53 to the Italian term “prova” which means “test”, that is the amount of curd taken during manufacturing
54 to control the stretching rate. The Provola cheese is generally waxed by microcrystalline wax after
55 ripening, to preserve the product by moisture loss and external agents. Calabrian Provola cheese
56 (CPC) is produced in the Calabria region (South Italy), and is traditionally from the Crotona’s
57 province. Local producers bond Provola cheese with a natural fibre string and sold it fresh or after
58 few days by production. In particular pasta filata cheese needed to be packaged to limit the water
59 evaporation and prevent oxidation reaction that which causes colour changes, off-flavour production
60 and loss of nutrients. The textural food properties are linked to the breakdown of the proteins and in
61 successive free amino acid release. Many studies evidenced the influence of packaging on the quality
62 preservation of dairy products (Pintado & Malcata, 2000, Mortensen, Bertelsen, Mortensen, &
63 Stapelfel, 2004; Di Marzo et al., 2006; Favati, Galgano, & Pace, 2007; Papaioannou, Chouliara,
64 Karatapanis, Kontominas, & Savvaidis, 2007; Cakmakci, Gurses, & Gundogdu, 2011; Del Caro et
65 al., 2012). A proper storage is fundamental to preserve the original nutrients and hygienic

66 characteristics of food products, as well as their typicality. The transparent packaging is greatly
67 demanded by consumers, to better appraise the cheese prior to purchase. The use of some plastic
68 materials, as PET (Polyethylene terephthalate), PVC (Polyvinylchloride), PE (Polyethylene), PP
69 (Polypropylene), PS (Polystyrene), PA (Polyamide) has been increased in food packaging, often
70 combined in multilayer structures, because they are largely available, low-cost and show good
71 physical properties, among which the heat sealability, the structural strength, the barrier to gas and
72 volatile compounds. They are not totally recyclable or biodegradable, so their use has to be restricted
73 (Siracusa, Rocculi, Romani, & Dalla Rosa, 2008). Different polymers are present in the market used
74 principally as films or trays: some of these originate from petrochemical monomers, like some types
75 of polyester, polyester amides and polyvinyl alcohol. The bio-based polymers are represented by
76 starch materials, cellulose-based materials, polylactic acid (Polyester, PLA), polyhydroxy acid
77 (polyester, PHA) and other ones. Cellophane is a cellulose-based biopolymer, obtained from natural
78 resources like cotton, wood, wheat and corn. The cellophane is composed by regenerated cellulose, a
79 softening agent, and water as plasticizer. It offers a good gas barrier when kept dry and further surface
80 (friction, antistatic and antifog) properties can be showed when it coated. Despite some positive
81 properties of cellophane (heat resistance, strength, clarity, and barrier to gas), this bio-based material
82 shows a limited shelf life for a loss of volatile plasticizer that make brittle it and reducing the shelf
83 life of food contained in (Yam, 2010). The PLA is produced by depolymerization of the monomer of
84 lactic acid deriving from fermented and biodegradable substances of different origin (Cabedo, Luis
85 Feijoo, Pilar Villanueva, Lagarón, & Giménez, 2006). Literature reports that the choice of PLA as
86 'green' packaging material is growing because it often shows a better performance than the
87 conventional plastic materials, for example the oriented polystyrene and polyethylenterephthalate
88 (Auras, Singh, & Singh, 2005). Moreover, PLA is recyclable and compostable, shows good optical
89 properties, processability and water solubility resistance. Several studies proved the PLA to be
90 suitable for packaging of some cheeses in modified atmosphere (Ahmed & Varshney, 2011; Holm,
91 Mortensen, & Risbo, 2006; Dukalska et al., 2011; Plackett et al., 2006; Dmytrów, Szczepanik, Kryża,

92 Mituniewicz-Małek, & Lisiecki (2011). The use of biopolymers shows some critical issues, regarding
93 the cost, the performance and the processing. Concerning these last two, the problems are more
94 evident in materials derived from bio-mass, such as cellulose or starch (Petersen et al., 1999).
95 In a previous study, Piscopo, Zappia, De Bruno, & Poiana (2015) investigated the improvement of
96 quality of CPc, under different types of packaging: vacuum and modified atmosphere in two forms:
97 thermoformed tray and pouch. Results suggested that the packaging in pouch with MAP (70:30
98 N₂:CO₂), using high barrier material (Polyethylene/Ethylene vinyl alcohol/Polyamide/Polyethylene)
99 was the best solution to preserve these dairy products. Based on these results, in this work the use of
100 biodegradable materials with different permeabilities to gas and water vapour was studied as an
101 alternative to the high barrier petrochemical-based material currently used for the preservation of the
102 quality of Provola cheese produced in Calabria.

103

104 2. Materials and methods

105 2.1 Experimental procedure

106 Fresh Calabrian Provola cheeses (CPc) were produced in Cimino & Ioppoli s.r.l. company located in
107 Crotone (Italy) using the procedures and showing the characteristics described by Piscopo et al.
108 (2015). Twenty-four hours after cheesemaking, the cheeses (mean weight of 0.5 kg) were packed in
109 pouches (20 x 28 cm²) of three different packaging materials, namely: one multilayer co-extruded
110 film (A) and two bio-based polymers (B and C). The sealing of pouches was performed by a Tecnovac
111 S100 DGT chamber machine (Bergamo, Italy) in modified atmosphere constituted of 70% N₂ and
112 30% CO₂. The film A was a coextruded multilayers of Polyethylene/Ethylene vinyl
113 alcohol/Polyamide/Polyethylene (PE/EVOH/PA/PE), 70 µm (Krehalon, USA), the film B consisted
114 of PLA, coated with a silicon oxide barrier (Ceramis Amcor, Italy) 42 µm, and the material C was a
115 cellophane film coated with a proprietary barrier and sealable layer (NVS coated Natureflex™,
116 Carton pack, Italy), 28 µm.

117 Qualitative changes were monitored up to 65 days (beyond the commercial expiry date of 45 days
118 without packaging) on cheeses stored in refrigerated incubators (mod. Foc 225 I Velp Scientifica,
119 Italy) at two different temperatures: 4 °C as optimal temperature for cheese storage and 7 °C as the
120 temperature to which food are generally stored in exhibiting refrigerators of supermarkets.

121 2.2 Standards and reagents

122 All chemicals were of analytical reagent grade. Methanol, chloroform, methylene chloride were of
123 HPLC grade from Carlo Erba reagents (Italy). Pure standards of triglycerides (trimyristin, tripalmitin,
124 triolein), diglycerides (dimyristin, dipalmitin, diolein) and monoglycerides (monomyristin,
125 monopalmitin, monoolein) were obtained by Sigma-Aldrich Chemicals Co. (S. Louis, Missouri).

126 2.3 Gas and water vapour permeability measurements

127 The oxygen transmission rate (OTR), carbon dioxide transmission rate (CO₂TR) and water vapour
128 transmission rate (WVTR) of packaging materials were performed in accordance with ASTM D3985
129 for oxygen, ASTM F2476 for carbon dioxide and ASTM F1249 for water vapour by an iso-static
130 permeabilimeter at 23 °C and different values of relative humidity (mod. MultiPerm, ExtraSolution®,
131 TotalPerm, Italy).

132 2.4 Physical, microbiological, and chemical analyses of Calabrian Provola cheeses

133 The gas composition inside the packaging, expressed as O₂ and CO₂ percentages, was detected by a
134 gas analyser (CheckPoint; PBI Dansensor, Ringstedt, Denmark). The volume taken from the package
135 headspace was of 15 cm³. The measurement was replicated in three packages for each sample.

136 The Total Bacterial Count (TBC) was performed by inoculation at 25 °C for 48 h of diluted minced
137 cheeses in Plate Count Agar (PCA) medium (Oxoid, Milan, Italy) according to ISO 4833:2003
138 method and expressed as colony forming units (cfu)/g of CPc. Analysis was made in three replicates.

139 The colour coordinates of the CIELAB space (L*, a* and b*) were randomly monitored in five points
140 of the CPc surface by a tristimulus colorimeter (Konica Minolta CM-700d, Osaka, Japan) referred to
141 the D65 illuminant. Measurements were performed in three replicates. Total colour difference (ΔE)

142 in surface and inner layer of Provola cheeses before the packaging and after 65 days of storage was
143 obtained by the following formula (Thompson, 2004):

$$144 \quad CD = \sqrt{((L^*-L^*_0)^2 + (a^*-a^*_0)^2 + (b^*-b^*_0)^2)}$$

145 where L^*_0 , a^*_0 , and b^*_0 are the initial values, obtained before packaging.

146 Moisture (%), pH and total acidity of cheeses were calculated according to AOAC methods (AOAC,
147 1980a; 1980b; 1990); water activity (a_w) of minced Provola cheeses was measured by Aqualab LITE
148 hygrometer (Decagon devices Inc., Washington USA). The Peroxide values were quantified
149 according European Union Commission (1991) in the cheese lipids, previously extracted following
150 the method reported by Folch, Lees, & Sloane-Stanley (1957).

151 For the mono-, di- and tri-glycerides content analysis, the samples were obtained according to Gomes
152 & Caponio (1999) and injected (20 μ L) into a HPLC (mod. Smartline Pump 1000 Knauer, Berlin,
153 Germany), provided of RI Detector 2300 (Knauer). Two-column series PLgel 5 μ m (column length
154 300 mm, ID 7.5 mm, 100 \AA) (Polymer Laboratories (United Kingdom) fitted with a guard column
155 PLgel 5 μ m (column length 50 mm, ID 7.5 mm) (Polymer Laboratories (United Kingdom) were used.
156 The flow rate of solvent was 1 mL min^{-1} and analysis was carried out at ambient temperature. The
157 used mobile phase was CH_2Cl_2 . Pure standards were used to identify the compounds which were after
158 quantified by derivative areas (%). The results were also elaborated to achieve the Lipolysis Index
159 (LI) by the following formula:

$$160 \quad \text{LI \%} = \text{FFA/L} * 100$$

161 where FFA: Free Fatty acids (g/100 g) and L: Lipid content (g/100 g).

162 All the reported analyses were performed in triplicate taking samples from the six cheeses.

163 For textural analysis of CPC authors followed the method, equipment and instrumental parameters
164 reported in a previous published work on Provola cheeses (Piscopo, Zappia, De Bruno, & Poiana,
165 2015). The Total Nitrogen (TN) of samples was quantified as described by Lynch & Barbano (2002).
166 For the Water Soluble Nitrogen (WSN) Kjeldahl's method was applied, as reported by Christensen,
167 Bech, & Werner (1991).

168 The Proteolysis Index (PI) % was calculated following the formula:

$$169 \text{ PI \%} = \text{WSN/TN} * 100$$

170 where WSN: Water Soluble Nitrogen (%) and TN: Total Nitrogen content (%)

171 2.3 Statistical analysis

172 The data statistical elaboration was performed by One-way and multivariate analysis of variance by
173 using of SPSS software (Version 15.0, SPSS Inc., Chicago, IL, USA). Tukey Post-hoc test was
174 conducted to evidence significant differences among samples.

175

176 3. Results and discussion

177 3.1 Gas and vapour transmission rates of the packaging materials

178 Comparisons of tested biodegradable polymers, B and C, and conventional plastic material, A,
179 revealed that OTR measured at 23 °C and 50% RH of A is three and five times lower than B and C
180 respectively. These results are related to the presence in the film A of EVOH, one of the lowest
181 oxygen permeability reported among polymers commonly used in packaging. It provided better
182 barrier properties than those observed in PLA with SiO_x and in cellophane coated with resins.
183 Moreover, a progressive higher oxygen permeability was observed in A and C materials with the
184 increasing of relative humidity: it can be explained by the EVOH and cellophane high-sensitivity to
185 moisture, as illustrated in literature (Zhang, Britt, & Tung, 2001; Muramatsu et al., 2003; Hernandez
186 & Giacin, 1998, Del Nobile, Buonocore, Dainelli, Battaglia, & Nicolais, 2002). The CO₂TR of A film
187 was one and two order of magnitude lower than B and C respectively, confirming that the presence
188 of EVOH gives a good CO₂ barrier (Maes et al., 2017). Despite the molecular diameter of carbon
189 dioxide is bigger than the molecule of oxygen, the CO₂TR through the PLA polymer was very higher
190 than the OTR, as also observed by Siracusa, Dalla Rosa, & Iordanskii (2017). This is due to the
191 different behaviour of CO₂ in terms of solubility and diffusion through the polymeric chain.
192 Regarding the water vapour, the highest barrier was opposed by PLA film (0.8 g/m² 24h), similar to

193 the result for A film ($1.3 \text{ g/m}^2 \text{ 24h}$), whereas cellophane film manifested the greatest WVTR, despite
194 the presence of resins in its surface.

195

196 3.2 Microbiological, physical and chemical analyses of Calabrian Provola cheeses

197 Confirming the diffusional properties of materials reported in Table 1, the O_2 percentages of the
198 atmosphere inside the biodegradable packaging (B and C) were higher with respect those measured
199 in plastic packages (A) from the initial time of storage to 35 days (Fig.1). After this period, the same
200 concentration of O_2 was observed in all pouches.

201 Perceptual increases of CO_2 were observed in packaging A and B. Concerning the first packaging,
202 the increase of CO_2 was due to the highest barrier properties of the EVOH layer that involved a higher
203 CO_2 retention inside the internal atmosphere respect to the B samples. The trend of CO_2 during
204 storage in B pouches resulted from both the permeability of film and the active microbial metabolism,
205 as evidenced in total microbial counts at both temperatures (Figure 2). The total microbial growth did
206 not produce an increase of CO_2 percentage in the internal atmosphere of C samples because of the
207 greatest transmission rate of the cellophane material. That physical characteristic of cellophane film
208 involved a leaving of CO_2 outside the package, naturally formed during cheese storage.

209 The multivariate analysis of data evidenced a strong effect of packaging type ($p=0.000$), and no
210 influence ($P>0.05$) by the storage temperature and times in that qualitative parameter ($p = 0.078$ and
211 $p= 0.206$).

212 The physical and chemical parameters possessed by CPC after 65 days of storage are reported in Table
213 2. Regarding the ΔE measured in samples from the initial time and after 65 days of storage at both
214 temperatures, just noticeable values greater than 2 were often observed with the only exception of the
215 core of A sample. Similar values were evidenced in A and B, and the C sample manifested the highest
216 colour differences in both layers (about 30 in the surface and 15 in the core) probably due to the
217 submitted dehydration at the end of storage, as confirmed by the lowest values of a_w and moisture
218 reported in the same table. From the initial percentage of 48.52 ± 1.75 , the moisture content remained

219 constant in A and B samples ($p = 0.061$ and $p = 0.052$) during the monitoring times, whereas it
220 decreased in C sample, in particular after 21 days at 7 °C and after 35 days at 4 °C (data not shown),
221 due to the higher WVTR of the cellophane material. The pH value of cheeses before the storage
222 (5.86 ± 0.02) decreased with significance ($p < 0.01$) during the storage in all samples. The total acidity
223 of CPc was 0.30 ± 0.01 g of lactic acid/100 g of dry matter after manufacturing; in particular, the total
224 acidity of Provola cheeses packaged in PLA increased after 65 days of storage at both temperatures
225 (0.53 ± 0.05 g of lactic acid/100 g of dry matter). The Peroxide value measured in CPc after
226 manufacturing was of 1.90 ± 0.50 mEq O₂/kg. This parameter after 65 days significantly varied on the
227 samples, in particular the highest number was observed in A sample stored at 4 °C, whereas at 7 °C
228 it was observed a higher amount in the C sample. Positive Pearson's correlation coefficients resulted
229 for cheese PV and O₂ % in the packages after 65 days at both temperatures ($r = 0.920$ $P < 0.01$; $r =$
230 0.910 $P < 0.01$).

231 Textural analysis showed a higher hardness in sample packaged in cellophane, with the following
232 order at both temperatures: C>B>A (Table 2). The increase of the penetration force on the sample
233 was due to a variation of moisture, as reported by several studies (Delgado, Gonzàles-Crespo, Cava,
234 Ramìrez, 2011; Dmytrów, Mituniewicz-Małek, Dmytrów, & Antonowicz, 2009; Bonczar &
235 Walczycka, 2001). Positive correlations were in fact evidenced by the Pearson correlation coefficients
236 between hardness and dry matter in A ($r = 0.665$ $P < 0.05$), B ($r = 0.854$ $P < 0.05$), and C ($r = 0.656$
237 $P < 0.05$). The expected consistence of CPc by a habitual consumer is certainly soft and not excessively
238 hard, as other "pasta filata" cheeses that are subjected to a ripening. So, the results of textural analysis
239 evidenced no positive characteristics in C sample, that is the Provola packaged in cellophane film at
240 both storage temperatures.

241 The influence on physical and chemical parameters of the variables 'Packaging' and 'Temperature'
242 obtained by Two ways-ANOVA are illustrated in Table 3. Packaging materials influenced the various
243 qualitative parameters more than the applied storage temperatures which affected only a_w, pH, and
244 peroxide values.

245 The Figure 3 reports the lipolysis and proteolysis indices in CPc during the storage: they were
246 obtained by elaboration of the mean data for both storage temperatures because no significant
247 differences were observed. The LI% is determined by the analysis of mono-, di- and tri-glycerides
248 content. In cheeses packaged in biodegradable materials (B and C) their measured content did not
249 vary during the storage from 0 to 65 days at both temperatures (data not shown), so in graph a) the
250 LI% of B and C samples remained constant at the three monitoring times (about 8%). An increase of
251 diglycerides and free fatty acids was instead observed in A samples during the storage, with higher
252 values respect those observed in literature for higher aging-cheeses (Malacarne, Formaggione,
253 Franceschi, Summer, & Mariani, 2006) and it is reported in graph a) as the highest observed lipolysis
254 index (26%). The A sample packaged in conventional plastic material, manifested the highest
255 proteolysis index at the end of storage and at both temperatures (26-27%) (Figure 4, graph b). This is
256 probably correlated to their higher a_w respect the other cheeses that promoted the extension of
257 reaction. Texture analysis of cheeses also confirmed that A sample showed after 65 days of storage
258 the lowest force in Hardness measurement (3.48 N at 4 °C and 4.01 N at 7 °C), expression of
259 proteolysis progress. The cheeses packaged in biodegradable materials (B and C samples) manifested
260 instead the lowest percentage of proteolysis at the end of storage, ranging from 16 to 18%). In
261 particular, the cheese packaged in Cellophane denoted a negative correlation between proteolysis
262 index and dry matter percentage, expressed by Pearson coefficient ($r = -0.992$ $P < 0.01$).

263 4. Conclusions

264 Considering all experimentally obtained results, it can be affirmed that the packaging based on PLA
265 film in modified atmosphere can be suggested for Calabrian Provola cheese. Specifically, its shelf
266 life could be prolonged to 65 days with some characteristic comparable to the multilayer film (colour
267 difference during the storage and moisture). That material can be also considered a valid alternative
268 to the conventional plastic one because of a good performance in the Provola cheese storage, in
269 particular for the observed lower proteolysis and lipolysis indexes, and peroxide values. The tested
270 Cellophane film was not useful for this purpose because of the final physical and microbial parameters

271 measured on cheeses. This type of local dairy product can be thus packaged in biodegradable film
272 with barrier properties similar to those reported in this paper without losing its specific and safety
273 characteristics, and to gain a higher added value for the sustainability of its manufacturing.

274

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280

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390

Table 1 Physical characteristics of materials used for packaging of Provola cheeses

Packaging [§]	Thickness (µm)	Total Composition and layer ratio	Layer number	OTR (cc/m ² day)	CO ₂ TR (cc/m ² day)	WVTR (g/m ² day)
A	70±4	PE/EVOH/PE/PA 5/1/2/1	4	2.3 (23°C RH 50%)	9.5 (23°C RH 65%)	1.3 (23°C RH 65%)
				3.3 (23°C RH 75%)		
				3.6 (23°C RH 90%)		
B	42±2	PLA-SiO _x /PLA 1/1	2	6.8 (23°C RH 50%)	95 (23°C RH 65%)	0.8 (23°C RH 65%)
				8.3 (23°C RH 75%)		
				6.3 (23°C RH 90%)		
C	28	CP 1/1	2	11.5 (23°C RH 50%)	646.1 (23°C RH 65%)	30.8 (23°C RH 65%)
				52.3 (23°C RH 75%)		
				48.3 (23°C RH 90%)		

[§]A: multilayer co-extruded film (PE/EVOH/PA/PE); B: biobased film (PLA, coated with a silicon oxide barrier); C: biobased film (cellophane coated with resins)

Table 2 Physical and chemical parameters of Calabrian Provola cheeses after 65 days of storage

Temperature (°C)	4 °C				7 °C				
	Samples [§]	A	B	C	Sign	A	B	C	Sign.
ΔE	surface	18.83±1.44b	18.28±1.52b	30.61±2.03a	*	18.30±1.02b	18.81±1.72b	32.04±2.85a	*
	core	1.96±0.36c	11.18±1.62b	15.32±2.06a	**	2.64±0.77c	13.09±2.54b	15.75±1.11a	**
a _w		0.975±0.002a	0.969±0.000b	0.943±0.002c	**	0.975±0.000a	0.964±0.001b	0.943±0.000c	**
Moisture (%)		47.22±1.40a	49.22±0.19a	38.36±8.57b	**	47.41±0.97a	48.60±0.37a	35.04±8.42b	**
pH		5.50±0.03c	5.70±0.04a	5.60±0.02b	**	5.51±0.06b	5.72±0.05a	5.57±0.21ab	*
Total acidity (g % lactic acid/d.m.)		0.47±0.03ab	0.53±0.05a	0.43±0.12b	*	0.51±0.01a	0.53±0.02a	0.40±0.11b	**
Peroxide value (mEq O ₂ /Kg)		6.22±0.12a	2.08±0.12c	2.66±0.09b	**	3.86±0.09b	2.02±0.06c	6.16±0.22a	**
Hardness (N)		3.48±0.15c	8.94±0.24b	12.45±1.19a	**	4.01±0.27c	9.02±1.69b	12.42±0.82a	**

[§] For A, B and C see Table 1. Values are Means ± Standard Deviation (n=15 for ΔE; n=3 for a_w, moisture, pH, total acidity and peroxide value; n=9 for Hardness.) *Significance at P<0.05; **Significance at P<0.01. Data followed by different letters are significantly different by Tukey's multiple range test.

Table 3. Influence of packaging and storage temperature on physical and chemical parameters of Calabrian Provola cheeses

	Moisture		pH	Total acidity	Peroxide value	Hardness
Packaging (P)	**	**	**	**	**	**
Temperature (T)	n.s.	*	**	n.s.	**	n.s.
P x T	*	*	*	n.s.	**	n.s.

n.s., not significant; * Significance at $P < 0.05$; ** Significance at $P < 0.01$.

Fig. 1 Gas composition of different Provola cheeses samples during the storage at 4 and 7 °C (A: PE/EVOH/PA/PE; B: PLA-SiO_x, C: Cellophane coated with resins)

Fig. 2 Total microbial count in Provola cheeses stored with different packaging (A: PE/EVOH/PA/PE; B: PLA-SiO_x, C: cellophane coated with resins)

Fig. 3 Hydrolysis of principal components on Provola cheeses stored with different packaging: (A: PE/EVOH/PA/PE; B: PLA-SiO_x, C: cellophane coated with resins)- a) Lipolysis index % and b) Proteolysis index %. Different letters denoted significant differences by Tukey's multiple range test ($P < 0.05$).

Fig. 1

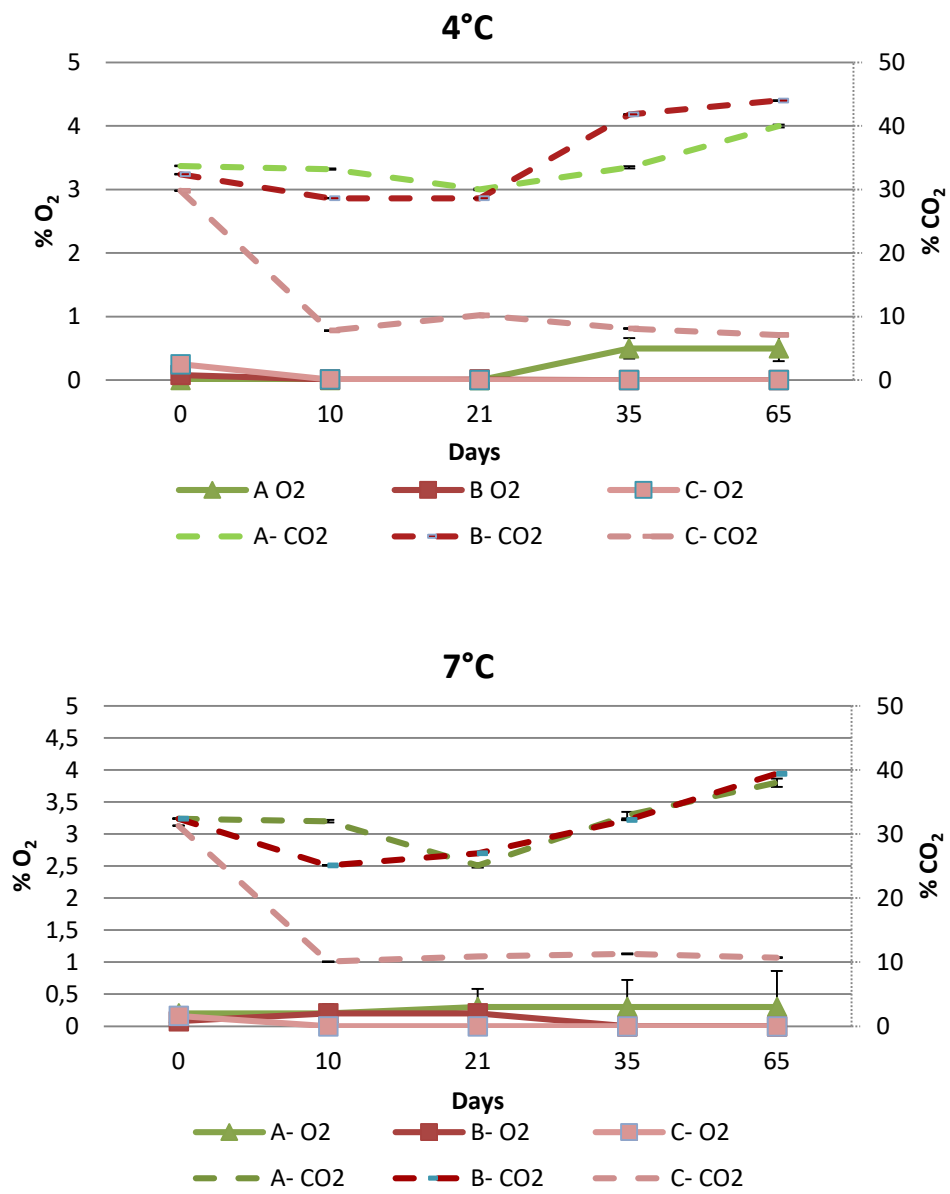


Fig. 2

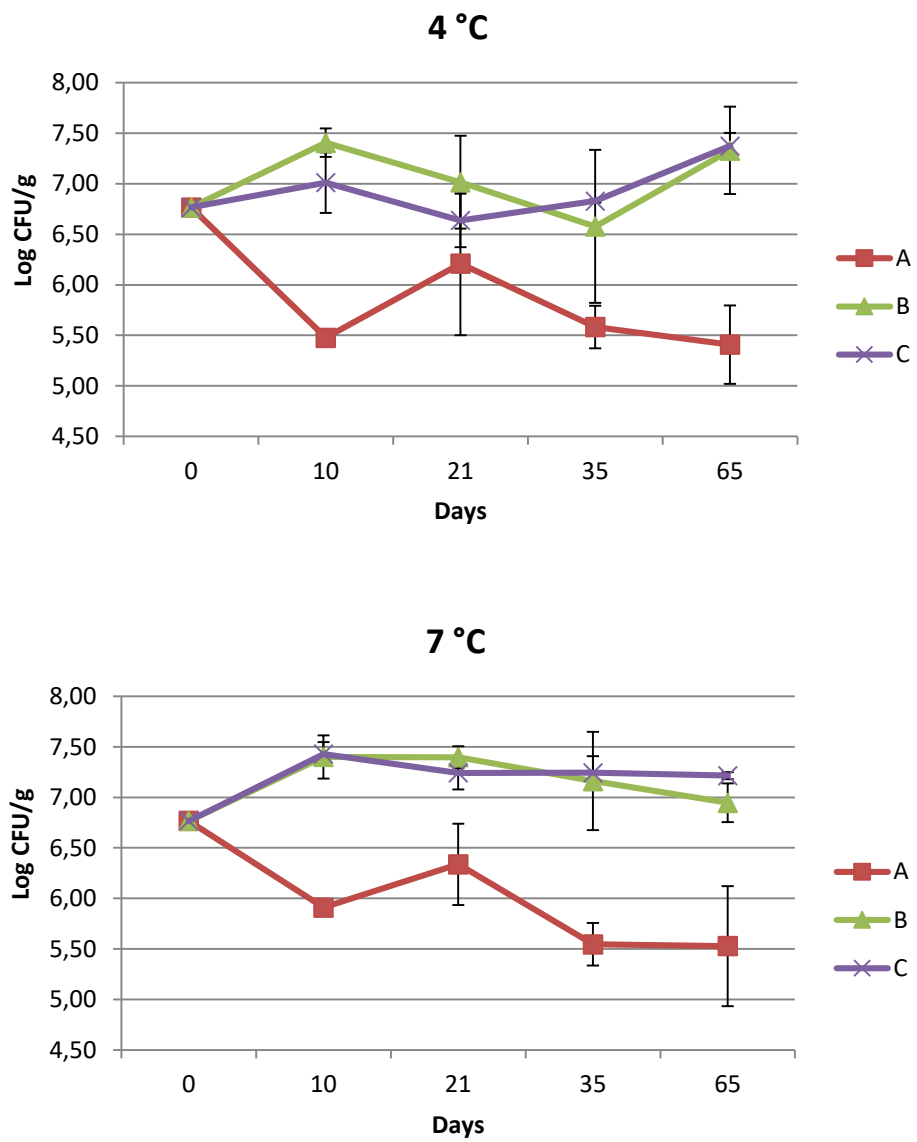
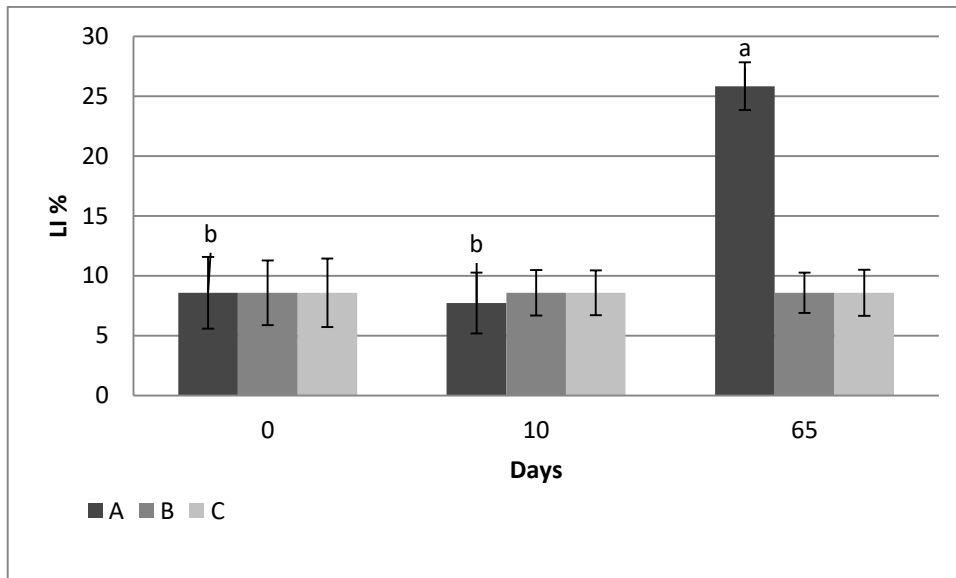


Fig. 3

a)



b)

