

QUALITY DECAY AND SHELF-LIFE STUDY OF FRESH CELERY (*Apium graveolens L.*) GROWN UNDER DIFFERENT NITROGEN FERTILIZATION

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1 **ABSTRACT**

2 Nitrogen fertilization is useful and widespread to obtain higher growth and quality of
3 productions. To evaluate the influence of nitrogen-rich fertilizers on the quality
4 characteristics, shelf-life tests of celery grown with two levels (80-120 kg ha⁻¹) of two
5 different nitrogen fertilizers were performed. Celery plants were selected and packed in two
6 plastic films (anti-fog polyolefin and micro-perforated polypropylene). Nitrate contents,
7 weight loss, hardness, changes in colour parameters and total phenols, were studied in both
8 packaging solutions during storage. Results showed that celery fertilized with organic
9 nitrogen and packed in anti-fog polyolefin reached a shelf-life of 37 days. Not treated sample
10 packed in micro-perforated polypropylene was not marketable after 20 days, while the same
11 sample packed in anti-fog polyolefin reached 30 days.

12 **Keywords:** Celery; nitrogen fertilization; shelf-life; quality.

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27 **1. Introduction**

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29 Celery (*Apium graveolens* L.) belongs to the Umbelliferae family (sin. Apiaceae), its water
30 content is around 90-96% and it is a hypo-calorific vegetable with only 15-20 kcal/100g of
31 edible portion.

32 In the European Community the main quality standards for celery marketability are reported
33 in the Reg. CE n.1591/87. Freshness, healthiness, cleanliness, but also weight and length
34 ranges of the celeries are clearly described, and products are consequently divided in first and
35 second class. Celery grows up to 30-40 cm tall and is composed of leaf-topped stalks arranged
36 in a conical shape that are joined at a common base. It is a biennial vegetable plant able to
37 grow spontaneously in wetland, and during the second year can develop empty stems up to 60
38 cm tall with white-green flower. Nitrogen fertilization determines a higher growth of plants,
39 an increase in the leaves system and higher yields. On the other hand, excess nitrogen could
40 cause plant diseases together with an increase in nitrates amount in the edible part of the
41 vegetable (Tei, Natalini, & Bruni, 2000). Consumers awareness of the relationship between
42 foods and health, together with environmental concerns, has led to an increased demand for
43 organic foods. Currently, celery stalks are available in markets as ready-to-eat vegetables,
44 thanks to new packaging solutions which regulate weight loss and gas exchange, keeping
45 freshness and quality longer (Robbs, Bartz, McFie, & Hodge, 1996). Celery washed and
46 chopped in little sticks, with its crunchy texture and distinctive flavour is a popular ingredient
47 in salads and many cooked dishes. The aim of this study was to assess the shelf-life of celery
48 plants as a function of different nitrogen supply in field and of different packaging materials.

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50 **2. Materials and methods**

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52 2.1. Chemicals

53 (N-morpholino)propanesulfonic acid, flavin adenine dinucleotide, microcystin,
54 polyvinylpyrrolidone, mercaptoethanol, etilendiaminotetracetate (all reagent grade), Folin-
55 Ciocalteu reagent, catechin (> 98 % purity) and sodium molybdate dihydrate were purchased
56 from Sigma-Aldrich S.r.l. (Milan, Italy); sodium fluoride, leupeptine and salycilic acid
57 respectively from Fluka,; Riedel-de-Haen (Hanover, Germany) and Applichem (Darmstadt,
58 Germany). Ethanol and water were analytical grade and were obtained from Lab-Scan (Milan,
59 Italy).

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61 2.2. Plant material, processing and storage conditions

62 Celery plants var. Dulce cv. D'Elne grown near Catania (Italy), were planted in lysimeter of
63 random squares on a medium composition soil (rich in C and P and pH 7.54). Plants were
64 treated with two different nitrogen fertilizers (ammonium sulphate and organic nitrogen as
65 water soluble peptides). Two levels (80-120 kg ha⁻¹) were used, and an untreated square was
66 kept as a control. All tests were performed in triplicate. Samples are referred to as T_n where n
67 is the nitrogen kind and amount used, as reported in Table 1. Sample R_n was grown in a part
68 of the field which had been treated as samples T_n one year before, while it was not treated
69 during this investigation. Celeries were harvested at commercial ripeness and brought to the
70 laboratory. After being carefully inspected, leaves and basal rosette were brushed to remove
71 any soil residues and each sample was weighed, packed and labelled and stored at 4 °C.

72 Two different films commonly used for fresh vegetables were used to pack celery: antifog
73 polyolefin (AF) and micro-perforated polypropylene (MP), both provided by System
74 Packaging s.r.l. (Siracusa, Italy). Non-perforated, antifog polyolefinic film (AF) (Clysar AFG-
75 E, France) is a co-extruded polyethylene and polypropylene film, while micro-perforated film
76 (MP) is a co-extruded polypropylene with a density of perforation of 7 holes/cm² (Bemis Le
77 Trait sas, France). Technical characteristics of packaging materials are reported in Table 2.

78 Nitrate contents were monitored in order to correlate the fertilization levels used with the

79 amount of N-NO_3^- recovered in field.. The following qualitative parameters were determined
80 twice a week: nitrate contents, weight loss, hardness and colour on petioles and total phenols.

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82 2.3. Relative humidity

83 Relative humidity was determined by AOAC method (AOAC, 1990).

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85 2.4. Nitrate contents

86 Two hundred milligrams of petioles and leaves were ground into powder in the presence of
87 liquid nitrogen containing 50 mM (N-morpholino)propanesulfonic acid in potassium
88 hydroxide, pH 7.8, 5 mM sodium fluoride, 1 μM sodium molybdate dihydrate, 10 μM Flavin
89 Adenine Dinucleotide, 1 μM leupeptine, 1 μM microcystin, 0.2 g/g fresh weight of
90 polyvinylpyrrolidone, 2 mM β -mercaptoethanol, and 5 mM etilendiaminotetracetate. The
91 crude homogenate was then centrifuged for 5 min at 12.000g and $+4^\circ\text{C}$. The NO_3^-
92 concentration was estimated from NO_2^- produced after nitrate reduction until a constant
93 concentration in the reaction medium was established. The metabolic nitrate concentration in
94 the tissue was proportional to the total nitrate obtained from the conventional salicylic acid
95 method (Cataldo, Haroon, Schrader, & Youngs, 1975). The complex formed by nitration of
96 salicylic acid under highly acidic conditions has a maximum absorption at 410 nm in basic
97 solutions (pH >12). Absorbance of the chromophore is directly proportional to the amount of
98 N-NO_3^- present. The nitrate concentration was expressed as $\text{mg NO}_3^- 100 \text{ g}^{-1}$ fresh matter.

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100 2.5. Weight loss

101 Weight loss was determined by weighing all samples with Chyo Balance MK-500C ($\pm 0,01 \text{ g}$)
102 (Japan) at the beginning and during the storage period. Results were calculated as the
103 difference between the final value and the initial weight and expressed as a percentage.

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105 2.6. Determination of hardness

106 Hardness measurement was performed at room temperature (24 ± 2 °C) by measuring the
107 maximum shear force using a Texture Analyzer TR[®] mod. 53205 (Forlì, Italy), fitted with a
108 stainless steel probe (diameter 5mm). For each celery, three stalks (internal, medium and
109 external) were tested (Rizzo, & Muratore, 2009). Celery stalks were penetrated in two points
110 for each node along each stalk . Data were recorded in duplicate and expressed as $N s^{-1}$.

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112 2.7. Colour development

113 Colour was measured on petioles surface at harvest and during storage using a portable
114 colorimeter (NR-3000, Nippon Denshoku Ind. Co. Ltd, Japan) calibrated with a standard
115 white tile (UE certificated) with illuminant C/2°, (light source used for the daylight),
116 according to CIE Lab scale. Colour was described as coordinates L, a and b (where L
117 measures relative lightness, a relative redness, and b relative yellowness). Colour were
118 measured on the petioles on two points for each node along each stalk. Results were
119 expressed also as hue and chroma ($C = (a^{*2} + b^{*2})^{1/2}$) (Gomez, & Artes, 2004). Hue is one of
120 the three main attributes of perceived colour in addition to lightness and chroma (or
121 colourfulness). Hue values were obtained as $\underline{h} = \tan^{-1} (b^*/a^*)$ when $a^*>0$ and $b^*>0$, or as $\underline{h} =$
122 $180^\circ + \tan^{-1} (b^*/a^*)$ when $a^*<0$ and $b^*>0$. Data were collected for the petioles as explained
123 for texture analysis.

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125 2.8. Determination of phenolic compounds

126 To determine the amount of the phenolic compounds celery samples were prepared as
127 previously described (Viña, & Chaves, 2006) and modified as follows. Fresh petioles were
128 chopped and homogenized; then 10 g mixed tissue were treated with 10 ml 96° ethanol for 60
129 minutes and then centrifuged (Centrifuge DR 15 B, Braun Biotech International, Melsungen,
130 Germany) for 30 min at 13135 g at 10°C. The supernatant was concentrated at reduced

131 pressure in a rotary evaporator (Laborota 4000-Efficient, Heidolph Instruments, Schwabach,
132 Germany) until dryness. Total phenols, expressed as mg catechin/100 g dry matter, were
133 quantified with Folin-Ciocalteu reagent (Singleton, & Rossi, 1965); absorbance readings were
134 carried out at 760 nm in a spectrophotometer (Shimadzu UV-2401 PC, Kyoto, Japan).

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136 2.9. Statistical analysis

137 Data reported are the average of 6 measurements. Results were analysed by means of a two-
138 way analysis of variance (ANOVA), using Tukey test to compare the means. Different letters
139 indicate significant differences at $P \leq 0.05$.

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141 **3. Results and discussion**

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143 Relative humidity (%) of petioles remained on similar levels (mean value 93.60 ± 0.60) in all
144 samples. In R4 and T2 the highest (94.31 %) and the lowest (92.81 %) values, respectively,
145 were observed (Fig. 1). Data from a survey on the nitrate content of vegetables in Italy and
146 other European countries range from 1700-2400 mg kg⁻¹ (Santamaria, 2006).

147 Nitrate contents were increased by nitrogen fertilization showing higher values in T2 (Table
148 3), having a good correlation with relative humidity ($R^2 = 0,966$). Nitrate contents showed
149 always lower values than the toxicity limits of the European Commission Regulation No.
150 563/2002 which sets limits for nitrate in lettuce and spinach.

151 Total nitrogen and proteins showed significant difference between our theses, with higher
152 levels in the treatments in comparison with the control. The Protein yield is a value able to
153 evaluate the efficiency of the system to use the nitrogen absorbed. Since the protein content is
154 strictly dependent on the nitrogen coming from the fertilization, the Protein yield shows the
155 absolute value of the capacity of the system to use nitrogen as protein, independently from
156 nitrogen enrichment. Protein yield (% N proteic/N total) showed values ranging from 1.42 to

157 1.55, respectively, in the control and T4 (Table 3). Others values of protein yield were similar
158 between treatments; this indicates a higher protein synthesis in the organic treatment
159 compared to the mineral ones, according to higher total nitrogen and nitrate accumulation in
160 T1 and T2.

161 Weight loss is a physiological event in fresh vegetables that can be limited by controlling
162 storage temperature and humidity, but also by using appropriate packaging. Taking into
163 consideration the classification of horticultural commodities according to ethylene production
164 levels made in previous studies, celery should be classified as a vegetable with a very low rate
165 (Gomez, & Artes, 2004). Weight loss in AF packaged celery was lower than 3% while in the
166 samples wrapped up in MP film, as expected, weight loss ranged from 30% to 52% after only
167 6 days at the end of the storage (Fig. 2). The organic fertilizer supplied to celeries determined
168 a shift of the standard weight loss observed for all the samples after 6 days. Both samples T3
169 and T4 showed the beginning of their weight loss after 10 and 13 days, respectively, when
170 packed in AF. AF film reduced weight loss of celery, minimized package condensation and
171 extended shelf life to beyond 31 days. In AF, relative humidity of samples did not change and
172 results were correlated with the weight loss ($R^2 = 0.772$).

173 Taking into account the different fertilization applied in soil, the weight loss observed during
174 the storage depends only from package and not from different nitrate contents in the petioles
175 ($R^2 = 0.27$ and $R^2 = 0.22$ respectively for AF and MP).

176 As known, hardness is a quality parameter, and it is a critical index of the overall
177 physiological conditions of vegetables, as reported by Vincent, Saunders, & Beyts, (2002).

178 Crispness and crunchiness are attributes of high quality products and are usually the most
179 relevant among consumer requirements. However, the distinction between crispy and crunchy
180 behavior is not very clear (Luyten, Plijter, & Van Vliet, 2004). Fillion and Kilcast (2002)
181 stated that crispness and crunchiness are very complex concept containing sound, fracture
182 characteristic, density and geometry of the product. Celery samples gave two kind of results,

183 for the first dimension ‘hardness’ and a different answer from panelists according the second
184 dimension probably due to its distinctive fibrousness (‘stringy’). Celery was judged as being
185 the crispest product between the six products selected for the experiments (carrot, celery,
186 cucumber, green pepper, Granny Smith and Golden Delicious apples). Untreated samples
187 packed in MP demonstrated a clear loss in hardness of celery petioles, with a shelf-life of 20
188 days; moreover the same packed in AF kept hardness until 31 days of storage (Fig. 3). This
189 result should be attributed to the performances of the AF film, which minimized the water
190 vapour loss extending the shelf life; indeed, shelf-life of celery is correlated with low weight
191 and relative humidity loss (Bogusława, & Sławomir, 2006). Considering the different theses,
192 celery plants grown under mineral nitrogen evidenced higher softening in the petioles,
193 showing a shelf-life of 31 days against the 40 days reached by samples treated with organic
194 nitrogen. The different behavior between the two nitrogen treatments could be caused by the
195 different amount of nitrates and relative humidity. In fact, in organic treated samples the
196 lowest nitrate content is linked with a higher water content, giving samples a better
197 consistence during storage. Among the different fertilizations (type and levels of nitrogen),
198 samples grown with the highest amount of both kind of nitrogen had the maximum values for
199 hardness of the petioles.

200 Colour is the most evident quality parameter for consumers, reason why hue and chroma
201 changes in petioles were considered (Rizzo, & Muratore, 2009). The hue angle showed a
202 course close to the foretold value, maintaining little variations for all samples (Tables 4, 5).
203 Chroma value decreased during storage, but it was well preserved by the anti-fog packaging,
204 in which T4 and R4 showed the best results. Until 31 days of storage the behaviour of the
205 mineral versus organic treatment was similar, but the organic thesis reached a shelf life of 37
206 (T4) and 40 (R4). In the micro-perforated film a rapid drop of the “colorfulness” occurred in
207 the first 17 days.

208 Total soluble phenols showed values ranging between 4.46 and 6.67 mg catechin 100g⁻¹ dry
209 matter (Table 3). Total phenols content decreased in all samples after 6 days until the end of
210 shelf-life, with the exclusion of mineral samples T1 and T2, in which these compounds
211 decreased after 10 days of storage (Fig. 4). Phenolic compounds constitute one of the most
212 important groups of natural antioxidants, owing to their diversity and extensive distribution.
213 They possess biological and chemical properties in common: reducing character, capacity of
214 sequestering reactive oxygen species (ROS) and several electrophiles, for chelating metallic
215 ions, tendency to self-oxidation and capacity for modulating the activity of some cell enzymes
216 (Viña, & Chaves, 2006). The phenolic composition of fruits is determined by genetic and
217 environmental factors but may be modified by oxidative reactions during processing and
218 storage, and the mechanisms involve their antioxidant activity and oxidative browning
219 (Robards, Prenzler, Tucker, Swatsitang, & Glover, 1999; Babic, Amiot, Nguyen-the, &
220 Aubert, 1993; Gil-Izquierdo, Gil, Conesa, & Ferreres, 2001; Alasalvar, Al-Farsi, Quantick,
221 Shahidi, & Wiktorowicz, 2005). The action of phenolics as antioxidants is assumed to be
222 beneficial in both foods and human body, where phenolics are oxidized prior to other food
223 constituents or cellular components or tissues. On the other hand, their role as substrates for
224 oxidative browning is probably restricted to foods and is invariably detrimental although, in
225 some instances, it is intentional and essential to the character of the product. During storage,
226 the decrease of these compounds might have positive effects as phenols are the best substrate
227 for polyphenoloxidases (PPO) and peroxidases (POD), enzymes responsible for the cell wall
228 degradation, in some measure confirmed by the correlation between total phenols and
229 hardness values ($R^2 = 0.43$). Although the oxidation of phenolic compounds leads to
230 discolouration, the products are considered as antioxidants. Browning is caused by
231 physiological events, which occur during ripening, or by side-effects of technological
232 processes, involving crushing or wounding. Cross-linked polymers formed by reactions of
233 protein functional groups have been indicated as the browning agents (Robards et al., 1999).

234 A significant correlation between the amount of total phenols and protein yield was observed
235 in both mineral and organic samples with a slightly higher value in the former ones ($R^2 = 0.99$
236 and $R^2 = 0.92$) respectively. Our results are coherent with literature: as previously described
237 by Sitaramaiah and Singh (1978), amendment of soil supplemented with NPK fertilizers
238 increased its phenolic content; as fruits and vegetables from organic cultivation contained
239 significantly more compounds with antioxidant properties (Kazimierczak, Hallmann,
240 Rusaczek, & Rembiałkowska, 2008; Shevtsova, Nilsson, Gallet, Zackrisson, & Jaderlund,
241 2005; Bavaresco & Eibach, 1987; Chassy, Bui, Renaud, Van Horn, & Mitchell, 2006).

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243 **4. Conclusions**

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245 N-NO₃⁻ contents in celery plants were influenced by nitrogen fertilization. Weight loss is a
246 physiological event in fresh vegetables and an important quality parameter that should be
247 considered and studied more to control different factors such as storage temperature, humidity
248 and mainly using the appropriate packaging solution. Sensory quality (colour, texture etc.) of
249 celery is also significantly influenced by growing practices and fertilisation. Particularly, the
250 optimization of irrigation and nitrogen levels has been thoroughly investigated to improve
251 crop quality but also in view of environmental considerations and farm economics (Raffo
252 Sinesio, Moneta, Nardo, Peparai, & Paoletti, 2006). The use of organic soil amendments has
253 been associated with desirable soil properties including higher plant available water holding
254 capacity (Bulluck, Brosius, Evanylo, & Ristaino, 2002). Clear differences in shelf-life were
255 observed: as expected, MP samples has a shorter shelf-life than AF ones. Celery fertilized
256 with organic nitrogen and packed in anti-fog polyolefin reached a shelf-life of 37 days. Not
257 treated sample packed in micro-perforated polypropylene was not marketable after 20 days,
258 while the same sample packed in anti-fog polyolefin reached 30 days. As expected, the anti-
259 fog polyolefin gave the best results, with the longest shelf-life, limiting the weight loss and

260 ensuring the best quality and hygienic conditions. Positive effect of the nitrogen fertilization
261 compared to the control were observed, and considering that the shelf-life of samples treated
262 with organic nitrogen is only 3 days longer in AF than in MF, looking at the economical
263 facilities, MF packaging could be recommended. Plants treated with organic nitrogen showed
264 an extending in the weight loss, and giving back a better shelf-life explained by the highest
265 hardness of the celery stalks linked with the highest concentration in antioxidant compound.
266 In conclusion, organic nitrogen supply together with MF packaging could achieve the best
267 result for the environment and for the economic management of agricultural cooperative.

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335 59.

336 **Figure captions**

337 **Fig. 1** Relative humidity percentage in petioles of celery

338 **Fig. 2** Percentage of weight loss in celery packaged in Anti-Fog (A) and in Micro-Perforated
339 (B) film during storage

340 **Fig. 3** Hardness in celery packaged in Anti-Fog and in Micro-Perforated film during storage:
341 (A) Control, T1 and T2; (B) Control, T3 and T4; (C) Control and R4

342 **Fig. 4** Total phenols in celery packaged in Anti-Fog and in Micro-Perforated film during
343 storage: (A) Control, T1 and T2; (B) Control, T3 and T4; (C) Control and R4.

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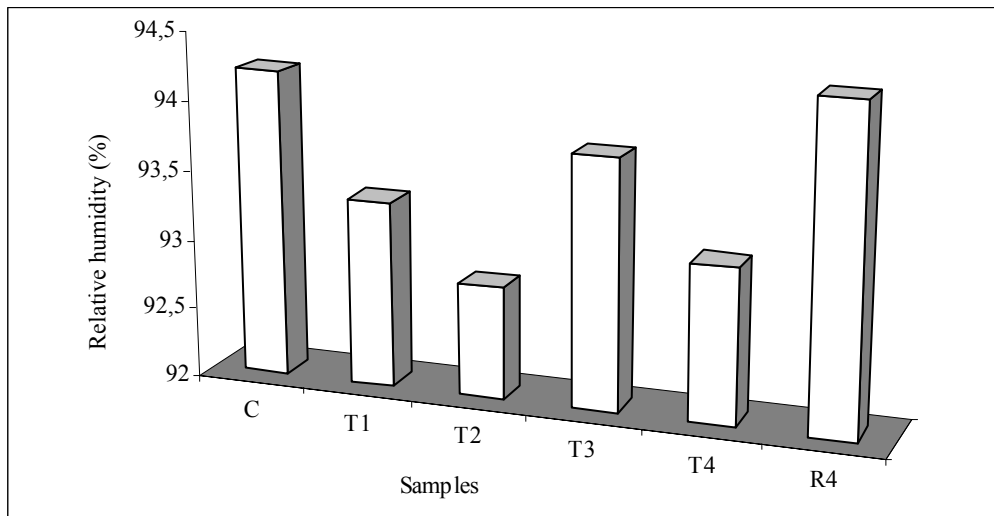
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362 Figure 1 Relative humidity percentage in petioles of celery. C is the control; T1 mineral
363 nitrogen 80 kg ha⁻¹; T2 mineral nitrogen 120 kg ha⁻¹; T3 organic nitrogen 80 kg ha⁻¹; T4
364 organic nitrogen 120 kg ha⁻¹; R4 residual organic nitrogen 120 kg ha⁻¹.



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384 Figure 2 Percentage of weight loss in celery packaged in Anti-Fog (a) and in Micro-
385 Perforated (b) film during storage. C is the control; T1 mineral nitrogen 80 kg ha⁻¹; T2
386 mineral nitrogen 120 kg ha⁻¹; T3 organic nitrogen 80 kg ha⁻¹; T4 organic nitrogen 120 kg ha⁻¹;
387 R4 residual organic nitrogen 120 kg ha⁻¹.
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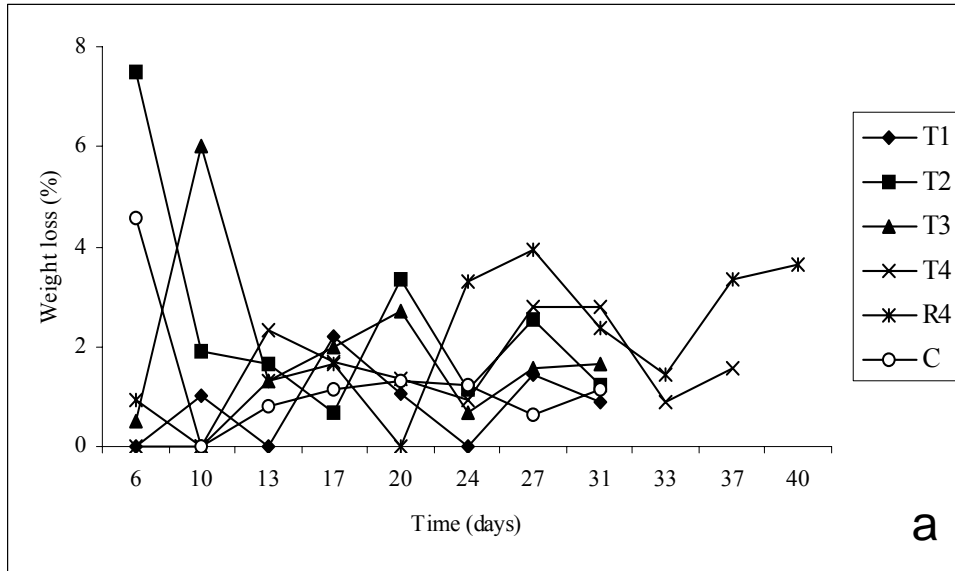
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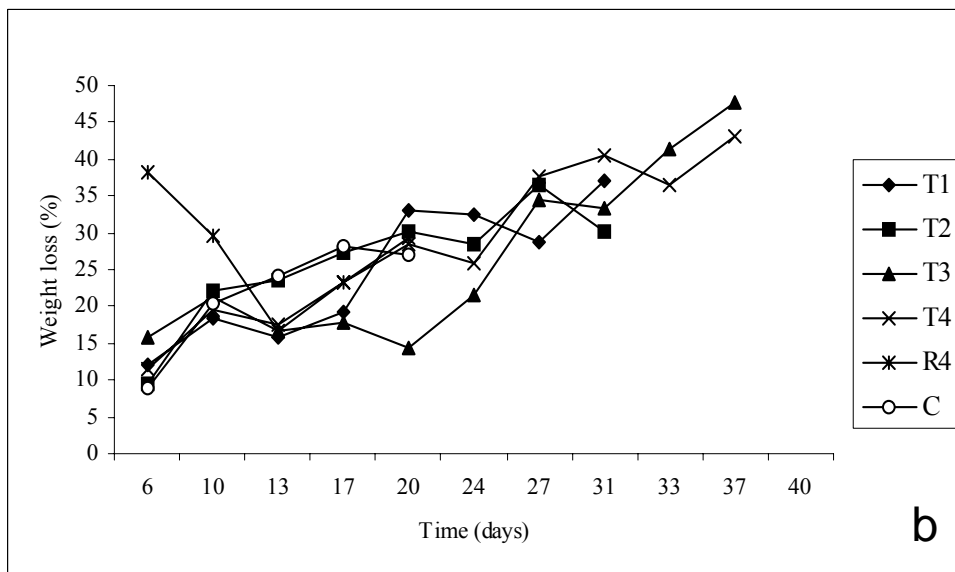
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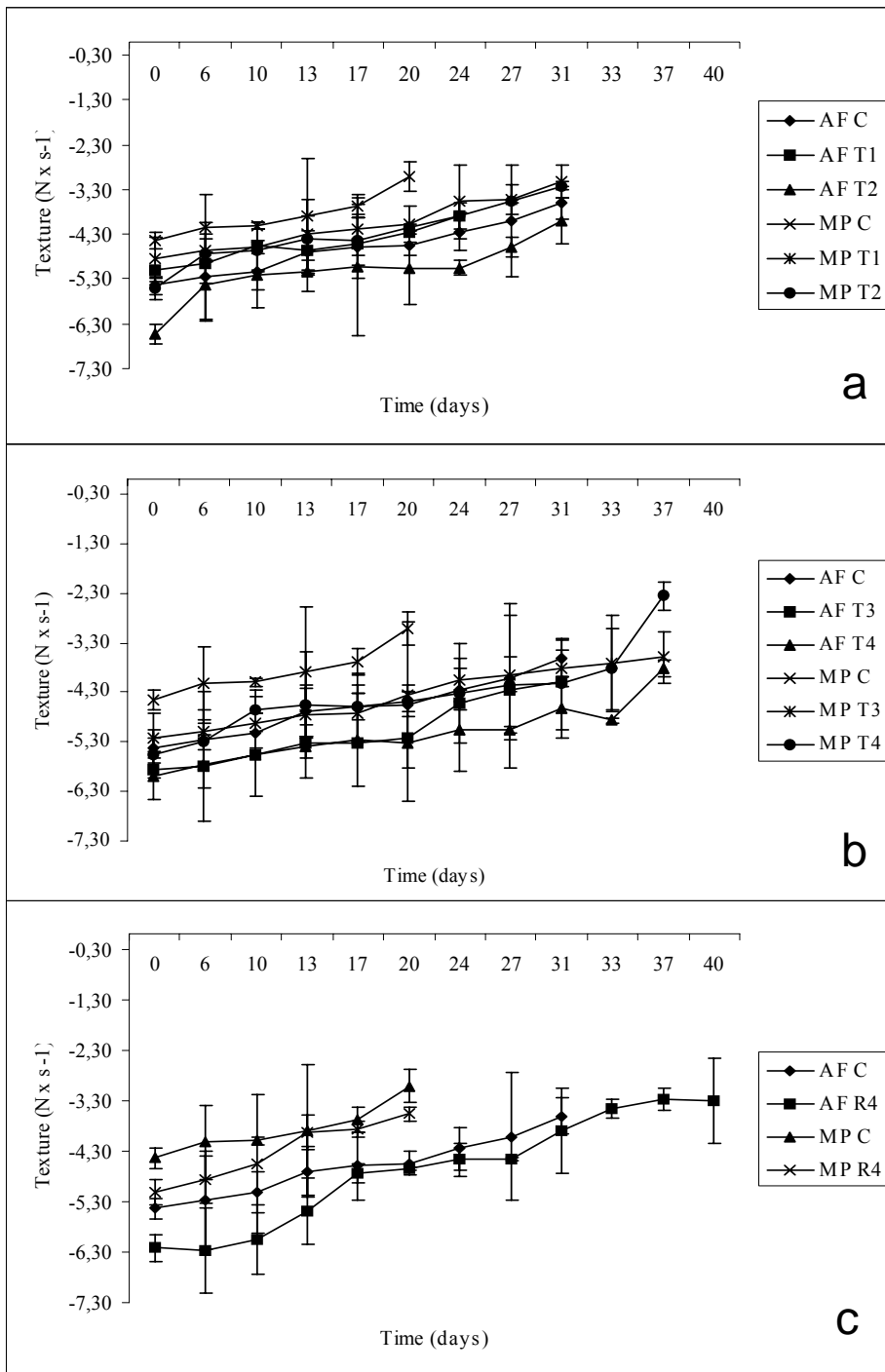
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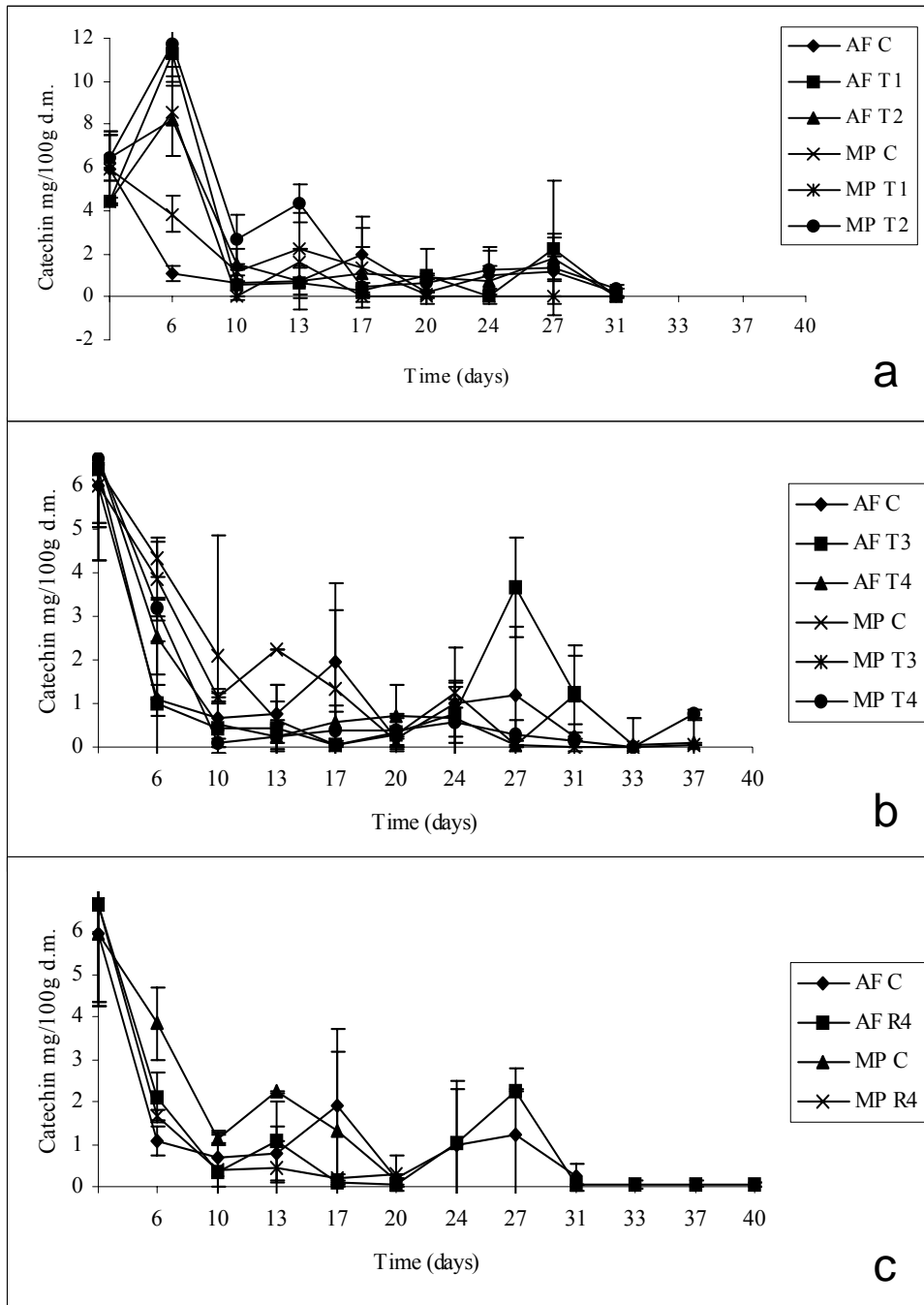
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Figure 3 Texture in celery packaged in Anti-Fog (AF) and in Micro-Perforated (MP) film during storage: (a) Control, T1 and T2 mineral nitrogen 80 and 120 kg ha⁻¹; (b) Control, T3 and T4 organic nitrogen 80 and 120 kg ha⁻¹; (c) Control and R4 residual organic nitrogen 120 kg ha⁻¹.



484 Figure 4 Total phenols expressed as catechin mg content on 100g of dry matter in celery
 485 packaged in Anti-Fog (AF) and in Micro-Perforated (MP) film during storage: (a) Control, T1
 486 and T2 mineral nitrogen 80 and 120 kg ha⁻¹; (b) Control, T3 and T4 organic nitrogen 80 and
 487 120 kg ha⁻¹; (c) Control and R4 residual organic nitrogen 120 kg ha⁻¹.



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500 **Table 1.** Treatment, source and quantity of nitrogen applied and N-NO₃⁻ amount in soil.

Sample	Source of nitrogen	Quantity of nitrogen (kg ha ⁻¹)	NO ₃ ⁻ (mg kg ⁻¹)
C	-	-	29.64
T1	Mineral	80	100.90
T2	Mineral	120	149.05
T3	Organic	80	37.80
T4	Organic	120	45.39
R4 (last year)	Residual organic	120	34.58

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541 **Table 2.** Principal technical characteristics of packaging films (data reported in market
 542 schedule).

Properties	Measurements Unit	AF value	MP value
Stiffness Modulus (avg)		193 Mpa	20000 Kg/cm ²
Thickness	µm	15	25
Elongation	%	150	210
Water Vapor Transmission Rate	g/m ² 24h	24,8	
Oxygen Transmission (PO ₂ g/m ² 24h atm)	cm ³ /m ² /24h	14000	
CO ₂ Transmission (PCO ₂ g/m ² 24h atm)	cm ³ /m ² /24h	36000	
Haze	%	3.0	
Gloss	%	110	
Weld ability range	°C		105/150

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579 **Table 3.** Total nitrogen (N), protein, proteic yield, nitrate (NO₃⁻) and total phenols in fresh
 580 petioles of celery at the beginning of the storage.

Sample	N (g 100g ⁻¹ d.m.)	Protein (mg g ⁻¹ f.m.)	Proteic yield (% N proteic/N total)	NO ₃ ⁻ (mg 100g ⁻¹ f.m.)	Total phenols (mg catechin 100g ⁻¹ d.m.)
C	0,55 e	0,51 e	1,42	247,68 d	4.46 c
T1	1,25 bc	1,19 c	1,52	518,22 b	6.58 a
T2	1,61 a	1,54 a	1,53	608,27 a	6.67 a
T3	1,15 c	1,11 cd	1,51	424,87 c	6.36 ab
T4	1,45 ab	1,40 b	1,55	486,04 b	6.42 a
R4 (last year)	1,00 d	0,96 d	1,54	264,55 d	5.96 b

581 Different letters are significantly different at P ≤ 0.05.

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622 **Table 4.** Hue in petioles of celery packaged in AF and MP film during storage.

Package	Treatment	Time (days)											
		0	6	10	13	17	20	24	27	31	33	37	40
AF	C	55.22	50.88	51.56	58.15	48.23	51.78	53.87	55.95	50.65	-	-	-
	T1	57.33	53.06	54.07	47.46	52.43	51.78	55.77	51.11	52.85	-	-	-
	T2	58.52	52.00	54.46	51.34	49.23	49.23	51.78	51.11	54.65	-	-	-
	T3	58.31	50.88	51.11	53.47	56.13	53.87	53.87	58.47	53.06	-	-	-
	T4	53.26	55.03	51.34	50.65	48.74	50.65	51.78	53.47	56.30	54.46	48.99	-
	R4	56.48	52.00	51.56	47.72	52.43	49.23	54.84	53.26	62.48	53.06	54.84	55.22
MP	C	55.22	57.00	58.47	56.83	56.48	53.26	-	-	-	-	-	-
	T1	57.33	59.68	54.84	53.06	52.64	51.34	54.84	54.26	55.22	-	-	-
	T2	58.52	58.31	53.47	58.31	53.67	55.22	55.95	54.46	54.07	-	-	-
	T3	58.31	57.00	54.46	49.72	50.88	53.06	55.95	54.65	53.26	56.65	54.84	-
	T4	53.26	57.66	53.87	56.48	60.39	54.07	54.07	54.84	50.65	57.17	54.65	-
	R4	56.48	60.80	53.87	54.26	50.42	54.65	-	-	-	-	-	-

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656 **Table 5.** Chroma in petioles of celery packaged in AF and MP film during storage.

Package	Treatment	Time (days)											
		0	6	10	13	17	20	24	27	31	33	37	40
AF	C	22.27	14.75	17.32	12.60	14.66	13.91	17.20	17.55	18.23	-	-	-
	T1	21.31	17.25	12.12	17.36	14.98	17.23	17.16	16.69	19.80	-	-	-
	T2	22.08	15.90	16.02	18.69	14.19	14.61	22.47	13.40	15.45	-	-	-
	T3	20.60	18.04	17.41	15.56	15.52	13.98	19.61	14.33	13.79	-	-	-
	T4	20.22	12.89	11.78	18.63	16.17	12.00	13.58	20.10	17.65	28.36	19.40	-
	R4	24.35	20.60	9.90	11.48	13.12	14.90	18.10	19.58	13.70	21.64	15.16	18.64
MP	C	22.27	24.72	10.28	11.88	10.18	17.18	-	-	-	-	-	-
	T1	21.31	23.08	17.31	12.99	15.09	11.24	17.46	17.45	16.61	-	-	-
	T2	22.08	26.16	16.47	6.96	13.28	16.27	17.33	18.29	17.89	-	-	-
	T3	20.60	22.10	15.95	12.60	11.03	20.66	18.38	15.71	16.67	26.99	16.04	-
	T4	20.22	20.24	16.93	12.56	10.04	16.40	16.20	15.61	17.49	25.89	17.57	-
	R4	24.35	15.69	13.01	12.25	13.79	17.49	-	-	-	-	-	-

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