# TEXTURE OF EXTRA VIRGIN OLIVE OIL-ENRICHED MASHED POTATOES: SENSORY, INSTRUMENTAL AND STRUCTURAL RELATIONSHIPS

MARÍA DOLORES ALVAREZ[1,3], CRISTINA FERNÁNDEZ[1], MARÍA JOSÉ JIMÉNEZ[2] and WENCESLAO CANET[1]

[1]Department of Characterization, Quality and Food Safety, Instituto de Ciencia y Tecnología de Alimentos y Nutrición (CSIC), José Antonio Novais 10, E-28040 Madrid, Spain
[2]USAS, Instituto de Ciencia y Tecnología de Alimentos y Nutrición (CSIC), José Antonio Novais 10, 28040 Madrid, Spain

**Running title**

OLIVE OIL EFFECT ON MASHED POTATO TEXTURE

[3]Corresponding author. TEL: +34-91-5492300; FAX: +34-91-5492300; EMAIL:mayoyes@ictan.csic.es

## ABSTRACT

The aim of this work was to study the effect of the addition of extra virgin olive oil (EVOO) on instrumental textural properties, sensory texture profile analysis (TPA) and microstructure of fresh and frozen/thawed mashed potatoes formulated without and with added cryoprotectants [kappa-carrageenan ($\kappa$-C) and xanthan gum (XG)]. EVOO behaves as soft filler due to droplet aggregates, whereas addition of cryoprotectants led to more structured mashed potatoes (MP) thanks to the gelling properties of $\kappa$-C. Both the percentage of added EVOO and processing had a much less significant effect on the texture of the MP containing $\kappa$-C and XG, evidencing the ability of this biopolymer blend to impart freeze/thaw stability. All samples with added EVOO were perceived as significantly softer and creamier than the samples without EVOO, whereas all MP samples with added cryoprotectants were perceived as significantly thicker and creamier than those without hydrocolloids.



## KEYWORDS

Extra virgin olive oil, mashed potatoes, texture, microstructure, TPA sensory attributes, freezing

## PRACTICAL APPLICATIONS

Previous studies showed that the quality after freezing and thawing may be improved by the addition of 1.5 g/kg of *κ*-C and 1.5 g/kg of XG, and/or incorporation of dietary fiber, improvement of mashed potatoes texture by retarding starch retrogradation and increasing water-holding capacity. Growing awareness of the link between diet and health is fast changing consumer habits, so that there has been increasing demand for foods with health enhancing properties. Extra virgin olive oil (EVOO) has important nutritional characteristics linked to its biophenol content and has very important antioxidant properties. The results have shown that although instrumental textural data were able to explain differences in consistency perceived, structural information is needed to understand differences in creaminess. Back extrusion test is recommended to industry as practical quality control tool in the commercial production of mashed potatoes with added EVOO.

## INTRODUCTION

Various health organizations recommend a daily intake of around 600 g of fruit and vegetables, but few people manage to consume this amount. Led by consumer demand, the food industry has shown an increased interest in the manufacture of healthier and more natural fruit and vegetable food products, such as soups, drinks and sauces (Whybrow *et al*. 2006). Mashed potatoes (MP) made from 100 % fresh potato tubers are in addition a natural vegetable semisolid food, which may also be suitable for freezing as a ready-meal component or as a product in itself such as potato gratin (Alvarez *et al*. 2009).

Olive oil is an important component of the diet of the countries surrounding the Mediterranean Sea. Due to its composition, olive oil is a good source of biophenols (Boskou and Visioli 2003) as well as lipid-soluble and water-soluble vitamins (tocopherols, β-carotene, ascorbic acid). In addition, thanks to its balanced fatty acid composition virgin olive oil has highly appreciated nutritional characteristics (Mildner-Szkudlarz and Jeleń 2010), known for a long time to the people of the Mediterranean region, who use it daily for a variety of culinary purposes. Biophenols with important antioxidant properties and a role in atherogenesis and cancer have been found and quantified in virgin and extra-virgin olive oils (Muniz 2007). However, consumption has also increased in non-Mediterranean areas thanks to growing interest in the Mediterranean diet and a belief that it prevents certain diseases (Boskou and Visioli 2003; Paraskevopoulou *et al*. 2005). A classic white sauce usually contains flour, milk and butter, but olive oil has been added to a white model-sauce to produce an innovative sauce approximating “Mediterranean cooking” (Mandala *et al*. 2004).

The oil volume fraction exerts profound effects on the physicochemical and viscoelastic properties of emulsions, such as droplet size distribution, creaming, oxidative

91 stability, and rheology (Dickinson and Chen 1999). Fat droplets influence the overall
92 physicochemical and sensory properties of foods in a variety of different ways
93 (Chantrapornchai *et al*. 1999). A great deal of research has been done on the influence of
94 fat droplets on the rheology, stability and flavour of food emulsions, but less is known
95 about their influence on emulsion appearance. Color is one of the major attributes affecting
96 consumer perception of the quality of virgin olive oil (Criado *et al*. 2008), and chloroplast
97 pigments (chlorophyll and carotenoids) are mainly responsible for the color of virgin olive
98 oil, ranging from yellow–green to greenish gold (Ayuso *et al*. 2004).

99 Texture is by far the most important quality criterion for consumer sensory acceptance
100 of freshly prepared and processed potato products, and particularly of frozen/thawed and
101 dehydrated mashed potatoes. A fluffy and medium-consistency texture is desirable,
102 whereas pastiness, gumminess and stickiness are negative attributes (Lamberti *et al*. 2004).
103 Texture instability remains the most significant challenge for frozen food products,
104 especially with inevitable post-production temperature fluctuations. Loss of moisture and
105 changes in textural attributes often result in significant reduction of product quality.

106 Previous studies showed that the addition of *κ*-C and XG to MP at a low concentration
107 (each cryoprotectant at 1.5 g/kg) is recommendable on the basis of overall acceptability,
108 especially when the product is going to be frozen (Alvarez *et al*. 2009; Fernández *et al*.
109 2009). *κ*-C provides the appropriate texture, while XG imparts creaminess and mouthfeel
110 to the product.

111 No research has been done on the addition of olive oil in fresh and frozen/thawed
112 mashed potatoes (designated FMP and F/TMP respectively), particularly with EVOO. The
113 use of EVOO rather than commercial olive oil is preferable because of its high
114 concentrations of both unsaturated fatty acids and antioxidant compounds such as
115 polyphenols and tocopherols (Severini *et al*. 2003). The purpose of the present research

was to evaluate the effects of adding EVOO on the textural, physical, structural and sensory characteristics of fresh and frozen/thawed mashed potatoes formulated without and with added cryoprotectants.

## MATERIALS AND METHODS

### Materials

The potatoes used were fresh tubers (cv Kennebec) from Aguilar de Campoo (Burgos, Spain) grown in 2008. *κ*-C (GENULACTA carrageenan type LP-60) and XG (Keltrol F [E]) were donated by Premium Ingredients, S.L. (Girona, Spain). EVOO (Carbonell, Spain) was chosen for addition to the MP. Following range-finding experiments, the lower and upper levels of EVOO to be used were set at 10 and 50 g/kg, respectively. A sample without EVOO was also prepared for each type of MP and processing conditions.

### Preparation of MP Samples

Tubers were manually washed, peeled and diced. MP were prepared in ~ 2000-g batches from 607.7 g/kg of potatoes, 230.8 g/kg of semi-skimmed in-bottle sterilized milk (fat content, 15.5 g/kg), 153.8 g/kg of water, 7.7 g/kg of salt (NaCl) and the corresponding EVOO concentration (0, 10, 25, and 50 g/kg) using a TM 31 food processor (Vorwerk España, M.S.L., S.C., Madrid, Spain). MP were prepared without and with added *κ*-C and XG (MPA and MPB samples, respectively). In the latter case, hydrocolloids (each at 1.5 g/kg) were also added to the rest of the ingredients in the form of a dry powder. All the ingredients were cooked for 35 min at 90C (blade speed: 40 rpm) (Alvarez *et al*. 2009;

Fernández *et al*. 2009). The mash was ground for 40 s (1200 rpm) and for 20 s (2600 rpm). The product was at once homogenized through a stainless steel sieve (diameter: 1.5 mm). The highest EVOO concentration was added twice to the MP to evaluate the effect of order of addition and EVOO thermal treatment on MP quality. First, 50 g/kg of EVOO was added along with the rest of the ingredients as indicated above, whereas in the second case the same EVOO concentration (designated "50b" g/kg) was added to the MP before final homogenization. Half of each fresh blend (FMP samples) was analysed immediately and the other half was frozen and thawed (F/TMP samples). Two repetitions of each composition were prepared in different weeks.

**Freezing, Thawing and Heating Procedures**

MP samples were placed on flat freezing and microwave thawing trays, and then frozen by forced convection with liquid nitrogen vapour in an Instron programmable chamber (model 3119-05, −70/+250C) at −60C until their thermal centres reached −24C (Fernández *et al*. 2009). After freezing, the samples were packed in polyethylene plastic bags, sealed under light vacuum (–0.05 MPa) on a Multivac packing machine (Sepp Haggenmüller KG, Wolfertschwenden, Germany), and placed in a domestic freezer for storage at −24C. Packed frozen samples were thawed in a Samsung M1712N microwave oven (Samsung Electronics S.A., Madrid, Spain). Samples were heated for 20 min at an output power rating of 600 W. Samples were brought up to 55C by placing them in a Hetofrig CB60VS water bath (Heto Lab Equipment A/S, Birker∅d, Denmark). Sample testing was 55C, where water and product temperatures were monitored by T-type thermocouples as described elsewhere (Alvarez *et al*. 2005, 2008, 2009; Fernández *et al*. 2008).

166 **Instrumental Texture Measurements**

167

168 Back extrusion (BE) and cone penetration (CP) mechanical tests were performed in order
169 to study the empirical rheological behavior of "semisolid like" samples. Both experiments
170 were performed using a TA.HDPlus Texture Analyser (Stable Micro Systems Ltd,
171 Godalming, UK) equipped with a 300 N load cell. During tests, MP samples were kept at
172 55C by means of a Temperature Controlled Peltier Cabinet (XT/PC) coupled to a separate
173 heat exchanger and proportional-integral-derivative control unit. For performance of BE
174 tests, a rig (model A/BE, Stable Micro Systems) was used consisting of a flat 45 mm
175 diameter perspex disc plunger that was driven into a larger perspex cylinder sample holder
176 (50 mm diameter) to force down into the MP samples and flow it upward through the
177 concentric annular space between plunger and the container. The measuring cup was filled
178 with 50 ± 1 g of MP. Product was extruded to a distance of 20 mm at 2 mm/s compression
179 rate. At this point (most likely to be the maximum force), the probe returns to its original
180 position. From the recorded force time curves, texture parameters with physical meaning
181 are calculated, which vary from simple consistency indices to a derived flow behavior
182 index, which is obtained according to the mathematical model suggested by Osorio and
183 Steffe (1987). In this study, maximum positive force of extrusion (firmness (N)) and the
184 negative area of extrusion (viscosity index (N s)) have been taken into account in order to
185 describe texture changing in MP samples. For performing the CP tests, a TTC spreadability
186 rig (HDP/SR, Stable Micro Systems) was used, consisting of a 45 degree conical perspex
187 probe (P/45 C) that penetrated a conical sample holder containing 7 ± 0.1 g of MP product.
188 Product was penetrated to a distance of 17.5 mm at 3 mm/s compression rate. CP work per
189 displaced volume ($J/m^3$) required to accomplish penetration was calculated from the area
190 under the curve up to the "peak" or maximum penetration force, and the average force of

the complete curve (N) was also recorded. Texture measurements were performed in quadruplicate and results averaged.

**Other Quality Parameters**

The color of the MP in the pots was measured with a HunterLab model D25 (Reston, VA, USA) color difference meter fitted with a 5 cm diameter aperture. Results were expressed in accordance with the CIELAB system with reference to illuminant D65 and a visual angle of 10°. The parameters determined were $L^*$, $a^*$ and $b^*$. A higher $L^*$ value indicated a brighter or whiter sample and values of $a^*$ and $b^*$ indicated red-green and yellow-blue colors. Yellowness index (YI) was calculated as $142.86b^*/L^*$ (Fernández *et al*. 2008).

Expressible water ($E_w$) was measured by centrifugal force. Centrifuge tubes containing approximately 10 g of MP were centrifuged at 15,000×g for 30 min in a Sorvall®, RC-5B apparatus (Global Medical Instrumentation, Inc, Clearwater, Minnesota, USA). $E_w$ was expressed as the percentage of liquid separated per total weight of sample in the centrifuge tube (Eliasson and Kim 1992). Measurements of color and $E_w$ were performed in quadruplicate and the results averaged.

**Sensory Analyses**

MP samples were subjected to texture profile analysis (TPA) modified to evaluate vegetables purees according to UNE 87025 (1996), which was used to select and define the sensory attributes included in the profile. A panel of 4 assessors, previously trained according to the ISO guidelines (ISO 8586-1:1993) and with specific exercise in MP for 8 years (Alvarez *et al*. 2005, 2008; Fernández *et al*. 2008), evaluated the textural attributes of

the samples. Profile attributes were classified into four groups (Alvarez *et al*. 2008). Attributes are listed in the order of the perception according to ISO guidelines (ISO 13299: 2003): attributes perceived before putting the sample in mouth (granularity and moisture (1)); attributes perceived at the time of putting the sample in the mouth (stickiness, denseness, homogeneity, moisture (2) and firmness); attributes perceived at the time of preparing the sample in the mouth for swallowing (cohesiveness, adhesiveness and fibrousness (1)); attributes perceived during final and residual phases of mastication (ease of swallowing, palate coating and fibrousness (2)). A description of the sensory attributes evaluated during the TPA can be found elsewhere (Alvarez *et al*. 2008).

Samples were evaluated, in duplicate, in morning sessions (11:00 a.m.-1:00 p.m.). Daily for 40 days assessors were given four samples (about 20 g each), for scoring attributes of each group in the texture profile. All the samples were served at 55 ± 1C on Petri dishes. This sample temperature was reached and kept constant by placing the product in the Hetofrig CB60VS water bath prior to testing. For each sample, panelists evaluated the perceived intensity of the 13 attributes on 8 cm descriptive linear scales labelled at each anchor: (left anchor: 1 = ‘‘not detectable; right anchor: 9 = ‘‘extremely intense’’). To reduce fatigue a rest period of 5 min was taken after scoring each sample.

MP samples were also subjected to an overall acceptability (OA) test based on all sensory attributes (texture, color, taste) on a 9-point hedonic scale (with 8 cm) labelled at each anchor: (left anchor: 1 = “dislike extremely”; right anchor: 9 = “like extremely”). In this case, sensory assessment was conducted by a 14-member untrained panel. Every day, one sample (about 20 g each) was served under the same conditions as indicated above.

**Scanning Electron Microscopy (SEM)**

MP microstructure was examined by SEM using a Hitachi model S-2.100 microscope (CENIM-CSIC). MP samples were air-dried, then mounted and sputter-coated with Au (200 A aprox.) in a SPI diode sputtering system metallizer. Photomicrographs were taken with a digital system Scanvision 1.2 of RONTEC (800x1.200 pixel).

**Statistical Analysis**

A three-way ANOVA with interactions was applied to evaluate how the three factors studied—EVOO concentration, presence or absence of hydrocolloids and performance or not of processing —affected the texture, color, sensory attributes and the OA of the MP. $E_w$ was always zero for the MPB samples; a two-way ANOVA with interactions was applied to evaluate how EVOO concentration and processing affected the $E_w$ of the products. Minimum significant differences were calculated using Fisher's least significant difference test (LSD, 99% for comparison of instrumental parameters and 95% for comparison of sensory attributes and OA). Analyses were performed with Statgraphics® software version 5.0 (STSC Inc., Rockville, MD, USA).

## RESULTS AND DISCUSSION

### Instrumental Texture Measurements

Table 1 shows the effects of EVOO concentration, cryoprotectant addition and processing on the values of the textural properties derived from the BE and CP tests. Samples with added *κ*-C and XG, as well as those subjected to freezing/thawing, presented significantly higher and lower textural properties than their respective counterparts. Previous studies showed that when *κ*-C/XG blends were added to FMP and F/TMP samples, *κ*-C provided the appropriate texture whereas XG imparted creaminess to the product (Alvarez *et al*. 2009; Fernández *et al*. 2009; Alvarez *et al*. in press). Analogously, in starch/XG blends, it was observed that XG does not interfere in potato starch network building (Mandala and Palogou (2003); Mandala *et al*. 2004). Therefore, addition of both hydrocolloids to MP produces a more structured system which is associated with the gelling properties of *κ*-C. In natural MP, the product was softer than the fresh control after freezing and thawing (Alvarez *et al*. 2005). MP is a starchy food, and as such may present quality problems such as syneresis and organoleptic and textural changes. These problems have been ascribed to phase separation caused by retrogradation of the starch (Eliasson and Kim 1992; Kim and Eliasson 1993).

With respect to the effect of EVOO addition, the maximum textural property values were registered in the samples without EVOO, although differences between textural properties of samples with 10 g/kg added EVOO and those without EVOO were non-significant (Table 1). However, increasing EVOO concentration produced softer, liquid-like systems, indicating that EVOO behave as soft filler. This result is to be expected as increasing concentrations of liquid oil are added to the product, increasing the oil-phase

286 volume fraction. In oil-in-water emulsions, the extent of the linear region decreased with
287 increasing oil-phase volume fraction from 20% to 40% v/v (Sun and Gunasekaran 2009).
288 For their part Dickinson and Chen (1999) suggested that oil/water emulsions may undergo
289 a behaviour transition from predominantly entropic behaviour to predominantly enthalpic
290 behaviour with increasing oil-phase volume fraction.

291 The analysis of variance also showed that the three binary interactions had a significant
292 effect on instrumental firmness, work per displaced volume and average force (Table 1).
293 This means that the effect of EVOO concentration on the texture depended on the presence
294 of $\kappa$-C and XG and on the freezing/thawing of the systems. Besides, AB and BC
295 interactions also significantly affected the viscosity index from the BE tests.

296 From the variation in the firmness value based on EVOO concentration for both MPA
297 and MPB samples shown in Fig. 1a, one can observe that firmness was lower in the MPA
298 than in the MPB samples; moreover, the variation in sample firmness was much greater
299 when EVOO content increased from 10 to 50 g/kg in the MPA samples than in the MPB
300 ones. Also, when the concentration of added EVOO was increased, the firmness value
301 behaved similarly in the FMP and F/TMP samples (Fig. 1b); in both cases, the increase in
302 EVOO content led to reduced firmness, without important differences between 50 and 50b
303 g/kg. As droplet concentration increases, the droplets are polydispersed and the samples
304 present a less close packing structure. In mayonnaise, increasing walnut oil content
305 increases the diameter of oil droplets and consequently reduces viscoelastic properties
306 (Cavella *et al*. 2009). From the variation in the firmness based on processing, the firmness
307 value developed differently for the MPA and MPB samples (Fig. 1c). Processing
308 significantly reduced sample firmness in the MPA samples but significantly increased it in
309 MPB samples. This behaviour can be explained taking account that much stronger and
310 more cohesive networks are formed when solutions of XG are frozen and thawed

311 (Giannouli and Morris 2003). The effect of XG may be explained by amylose/XG
312 interactions, which compete against amylose/amylose interactions, retarding or even
313 preventing retrogradation. Also, the addition of small amounts of XG to white sauces made
314 with starches from different sources significantly improves freeze/thaw stability (Arocas *et*
315 *al*. 2009).

316 In turn, the variation in average force with EVOO concentration for both MPA and
317 MPB samples (Fig. 1d) was similar to that observed in firmness. In this case, of the MPB
318 samples, the ones with 25 g/kg EVOO added had poorer consistency, whereas in the MPA
319 systems, the ones with 50 g/kg had poorer consistency. When the EVOO concentration was
320 increased the average force decreased in both FMP and F/TMP samples (Fig. 1e), although
321 in the latter case adding 10 g/kg EVOO slightly increased the average force as compared
322 with the control without EVOO. Both the BE firmness and the CP average force values
323 were greater when the EVOO was added after cooking (50b g/kg) in the FMP samples but
324 not in the F/TMP samples. When the processing-dependent variation in average force was
325 plotted (Fig. 1f), the changes in that value were also similar to those observed for firmness
326 (Fig. 1c). Plots for the viscosity index and the work per displaced volume have been
327 omitted for the sake of brevity.

328

329 **Color Measurements and Expressible Water**

330

331 All the three factors studied significantly changed the color parameters, although
332 processing did not significantly affect the yellowness index (YI) (Table 2). An increase in
333 EVOO level favours higher $L^*$ value (lightness) due to an increase in the overall light
334 scattering associated with the scattering properties of fat (Chantrapornchai *et al*. 1999). As
335 the EVOO concentration increased there was an increase in redness (decreasingly negative

336 *a** values) and in yellowness (YI), associated with the augmented pigment content of the
337 MP. The pigment profile of the virgin olive oil comprises chlorophyll a, chlorophyll b, and
338 derivative pigments associated with the acidic medium of the oil extraction process (Criado
339 *et al*. 2008).

340 *L** increased when *κ*-C and XG were added to the MP, which could be partially due
341 to their absolute water-holding capacity (WHC) as discussed below. Also, *a** was higher in
342 the MPB than in the MPA samples, indicating significant raised sample redness. The loss
343 of greenness associated with cryoprotectant addition was probably due to the presence of
344 XG in the system as found previously (Fernández *et al*. 2008). Increased lightness in the
345 F/TMP samples as compared to their FTM counterparts may have been partly due to the
346 formation of fissures produced by the growth of ice crystals during freezing, which favours
347 the release of water; this would transmit the light more rather than capturing it. For its part
348 the loss of greenness found in the processed samples (*a** values nearer to 0) as compared to
349 the fresh counterparts could be due to slight non-enzymatic browning (Maillard reaction)
350 during microwave thawing.

351 On the other hand, the three interactions had a significant effect on *L** and YI (Table
352 2). Moreover, AB and AC interactions significantly affected the *a** value. The variation in
353 the *L** value based on EVOO concentration in both MPA and MPB samples (Fig. 2a)
354 shows that increased EVOO concentration produced an increase in the *L** value in both
355 samples. The influence of droplet characteristics on the optical properties of colored oil-in-
356 water emulsions has been studied (Chantrapornchai *et al*. 1999). The lightness of the
357 emulsions increased with increasing droplet concentration and decreasing droplet size. As
358 the droplet concentration increases so does the reflectance because the droplets scatter light
359 more effectively and hence the light beam is unable to penetrate further into the product
360 and be absorbed.

The differences between the $L^*$ values of the MPA samples and their MPB counterparts increased with increasing the EVOO content (Fig. 2a). In emulsions, XG is added to the aqueous phase to prevent droplets from rapidly creaming and coalescence (Parker *et al*. 1995; Sun and Gunasekaran 2009). In this study oil droplet diameters were not measured, but it is probable that the droplets in the MPB samples were smaller than in the ones without cryoprotectants as the presence of XG in the system would prevent coalescence. The reason why the $L^*$ values were lower in the MPA samples, then, is that reflectance decreases with increasing droplet diameter. Note that in the MPB samples the $L^*$ value was greater when the EVOO was added after cooking (50b g/kg), whereas in the MPA systems it was greater in the samples with 50 g/kg EVOO added before cooking. This discrepancy could also be related to the presence of cryoprotectants in the system. MP with EVOO added before final homogenization would be expected to have larger droplets because the oil was not thoroughly triturated. In the presence of XG, the droplets scatter light more effectively when the oil is not so strongly entrapped in the matrix. In the MPA samples on the other hand, reflectance probably decreased because the scattering efficiency of the droplets decreases above a certain droplet size (Chantrapornchai *et al*. 1999).

In turn, as the droplet concentration increases, more reflected light travels through the oil phase of the MP being absorbed by the pigments mentioned earlier, intensifying the color of the MP (Figs. 2b, c). However, as regards YI values, there were small differences between FMP and F/TMP samples. Anyway, the color differences found between samples, although significant, should not be of major importance in practical terms.

$E_w$ changed significantly with EVOO concentration and processing (Table 2), and the AC interaction had a significant effect on the WHC of the samples (Fig. 2d). In this study, addition of $\kappa$-C and XG reduced the $E_w$ of both FMP and F/TMP samples to 0%, corroborating the well-established ability of XG to reduce water separation (Alvarez *et al*.

2008, 2009; Arocas *et al*. 2009), and evidencing the existence of XG-water or XG-water-XG interactions in the systems. XG is an anionic, hygroscopic material of exceptional pseudoplasticity (Baranowska *et al*. 2008); its texturizing effect can be achieved at low gum concentration because of unusual water-holding ability. Also, adding XG (0.3% w/w) to corn starch pastes (10% w/w) minimized amylose retrogradation, syneresis and rheological changes after freezing (Ferrero *et al*. 1994). Certainly, the $E_w$ values confirm that XG effectively stabilizes MP against syneresis when no more than 1.5 g/kg is added.

Besides, WHC was greater in the FMP samples than in their F/TMP counterparts at all EVOO concentrations (Fig. 2d). This result is probably related to structural damage caused by freezing. The addition of EVOO at low concentrations significantly increased $E_w$, mainly in the processed samples, which is likely due to that the interchain spaces were occupied by oil, displacing the water (Liehr and Kuliche 1996). However, the addition of EVOO at higher concentrations significantly reduced water loss, probably because excess oil hindered the release of water from the starch matrix. EVOO by itself was not effective in enhancing the WHC of MP. In any case $E_w$ percentages were also quite high (> 20) in both FMP and F/TMP samples without added EVOO, evidencing the presence of weak starch-water or starch-water-starch interactions in all the systems. Water separation in the MPA samples is related to starch retrogradation and consequent reduction of WHC (BeMiller and Whistler 1996).

**Sensory Analyses**

**Attributes perceived before putting the sample in mouth.** All the three main factors and their interactions significantly ($P < 0.05$) affected the scores for granularity and moisture (1) (Table 3). One can observe that at all EVOO concentrations granularity scores were

411 greater in the MPA samples (Fig. 3a) and likewise in the fresh products (Fig. 3b).
412 Christianson et al. (1981) indicated that gums like XG affect the gelatinization and
413 retrogradation of starch through strong associations with amylose, resulting in reduced
414 amylose-amylose interactions. In turn, presence of XG reduced granularity in the F/TMP
415 systems by assisting new starch/water interactions and consequent water absorption. In
416 both MPA and MPB samples, panelists judged granularity lowest in the samples with more
417 than 10 g/kg added EVOO. The effects of EVOO on granularity are related to the
418 lubricating and coating properties conferred by the oil as reported for vanilla custard
419 desserts (de Wijk *et al*. 2003).

420 In turn, moisture (1) decreased significantly with respect to MPA samples with the
421 addition of cryoprotectants in both FMP and F/TMP (Fig. 3c). Panelists detected greater
422 ability to hold water molecules in MPB samples, confirming the results for $E_w$ values.
423 Similarly, panelists detected less aqueousness in the processed samples than in the fresh
424 ones, probably due to water loss.

425

426 **Attributes perceived at the time of putting the sample in the mouth.** Stickiness scores
427 were significantly higher in the MPB samples, although there were no differences in these
428 scores as a consequence of EVOO concentration or processing (Table 3; Fig. 3d). In turn,
429 the three factors significantly affected scores for denseness, homogeneity, moisture (2) and
430 firmness. Denseness was significantly higher in the processed than in the fresh samples
431 only when EVOO was added at the highest concentrations (Fig. 3e). Also, denseness was
432 lower in the MPA than in the MPB samples (Fig. 3f), and only in this latter case were
433 denseness scores significantly higher in the F/TMP samples than in their FMP
434 counterparts.

When EVOO concentration was increased, homogeneity increased in both MPA and MPB samples (Fig. 3g). Note that the presence of EVOO in the systems rendered differences in homogeneity among MPA and MPB samples less appreciable. Also, when EVOO concentration was increased (Fig. 3h), homogeneity increased in the FMP products but was almost constant in the processed samples. This indicates a positive effect of adding EVOO to MP, since the negative effect of freezing on this attribute is masked by the oil. Panelists detected reduced moisture (2) in the MPB samples and in the processed systems, and when the EVOO concentration was increased, moisture (2) significantly increased when cryoprotectants were also added (Fig. 3i).

In turn, panelists detected reduced firmness in the samples with added EVOO, without added cryoprotectants and without processing. One can observe that the processed samples with the lower and higher EVOO concentrations were the firmest, whereas in the systems with 25 g $kg^{-1}$ added EVOO the fresh samples had similar firmness than the control (Fig. 4a). In the MPA samples there were no differences between firmness scores in fresh and processed samples (Fig. 4b); however, panelists detected increased firmness in processed MP with added $\kappa$-C and XG, matching the result for textural properties in MPB samples (Figs. 1c,f).

**Attributes perceived at the time of preparing the sample in the mouth for swallowing.**

EVOO concentration, cryoprotectant addition and processing also had a significant effect on cohesiveness, adhesiveness and fibrousness (1) (Table 3). When EVOO concentration was increased, cohesiveness and adhesiveness scores decreased significantly in the MPB samples (Figs. 4c,d). In the MPA samples there were no significant differences between the adhesiveness scores of fresh and processed samples (Fig. 4e), whereas panelists scored the processed MPB samples higher for adhesiveness than their fresh counterparts. Scores

for fibrousness (1) also decreased with increasing EVOO concentration, with cryoprotectant addition and with processing (Figs. 4f,g). Again, addition of cryprotectants reduced differences in fibrousness (1) between fresh and processed samples. This is probably related to the fact that the hydrocolloids can make systems in the rubbery state more viscous, reducing molecular mobility and preventing retrogradation (Ferrero *et al*. 1994).

**Attributes perceived during final and residual phases of mastication.** The three factors studied had a significant effect on ease of swallowing and fibrousness (2) (Table 4), whereas only EVOO concentration had a significant effect on palate coating. In samples both without and with added cryoprotectants (Fig. 4h) and in both FMP and F/TMP samples (Fig. 4i), ease of swallowing scores increased with increasing oil content. However, only when EVOO was added at concentrations of 0 and 10 g/kg, the scores for this attribute were higher in the samples without cryoprotectants and in the processed samples. Panelists also scored the samples with added EVOO significantly higher for palate coating than the ones made without EVOO (Figs. 5a,b). Scores for palate coating were higher in the MPA samples with 25 and 50 g/kg added EVOO than in their MPB counterparts (Fig. 5a), and the EVOO content had a much smaller effect in the F/TMP samples than in the fresh counterparts (Fig. 5b). Palate coating scores for MPA samples decreased after processing whereas scores for MPB samples increased with respect to the fresh products (Fig. 5c). Also, in the MPA samples, the addition of EVOO at all concentrations significantly reduced sample fibrousness (2) (Fig. 5d).

A complete dependence study was performed on the instrumental textural properties versus sensory attribute scores. Low correlations between instrumental and sensory ratings were found. Previous publications by other researchers generally agree on good to

485 excellent correlations for hardness (based on calculated "*r*" values (Szczesniak 2002).
486 Correlations for other parameters are usually less good and product-dependent. In this
487 study, relatively good correlations with sensory denseness and adhesiveness scores were
488 found only in the case of viscosity index ($R^2$ = 0.81 and 0.76, respectively). Differences in
489 consistency observed among samples were explained by viscosity index, but not the
490 variation in granularity or fibrousness, determining the sample creaminess.
491
492 **Overall acceptability.** EVOO concentration, cryoprotectant addition and processing had a
493 significant effect on the OA of the samples (Table 4). Scores for OA increased
494 significantly with increasing EVOO content in both MPA and MPB samples (Fig. 5e), and
495 likewise in both FMP and F/TMP samples (Fig. 5f). Similarly, a positive relationship
496 between oil content and sensory acceptability has been observed in a set of Polish
497 commercial mayonnaises (Juszack *et al*. 2003) and in salami (Severini *et al*. 2003). In this
498 study, the main differences between samples without and with added EVOO were ascribed
499 to either an aromatic or a creamy note detected in the oil-added MP. Samples with higher
500 percentages of EVOO produced less sensations of dryness and roughness, more sensations
501 of flavour, creamy and fatty mouth- and after-feel than the samples without added oil. Fat
502 is a well-known enhancer of creaminess sensations (de Wijk *et al*. 2003). The latter authors
503 suggested that the possible mechanism by which fat affects the sensory attributes include
504 lubrication and flavour release. The effects of fat on odour and flavour attributes may be
505 related to the flavour-releasing properties of fat.
506 Panelists scored the MPB and F/TMP samples higher for OA (Figs. 5e,f). This is
507 probably related to the presence of XG in the systems. It was found that samples
508 containing blends of *κ*-C and XG (Alvarez *et al*. 2009; Fernández *et al*. 2009), were
509 preferred organoleptically due to the creamy mouthfeel they produced. The effects of XG

on mouth texture may be related to its WHC as perceived by the panelists. Besides, in the processed MPB samples, there were no significant differences between the OA scores given to the MP at any concentration of added EVOO (which were the highest). This has important consequences for the formulation of EVOO-based MP. Results indicate that in the presence of $\kappa$-C and XG, if the EVOO content is reduced to below 25 g/kg, the OA score for the product does not decrease, and hence its consumer acceptability is not adversely affected.

**Microstructure Examination**

To achieve a better understanding of the sensory and rheological results and the effect of adding cryoprotectants and of freezing/thawing, the microstructure of the MP samples was studied by SEM (Figs. 6, 7). Fig. 6a shows a microphotograph of the fresh control without either added cryoprotectants or oil. Cooked cells are still distinguishable and firmly bound together by a continuous network of amylose. However, in the fresh control without added EVOO but with added cryoprotectants (Fig. 6b), less complete cells are visible, appearing separated from one another and embedded in a continuous network of amylose and $\kappa$-C in which starch granules and XG aggregates are entrapped. Probably, the presence of cryoprotectants occluding a great amount of water probably facilitated loss of the original cell shape.

Microphotographs of the corresponding processed counterparts (Figs. 6c,d) show that freezing and thawing of MPA and MPB samples resulted in completely dissolved cells. Part of the intracellular water was drawn out osmotically because of freezing-induced concentration of the cell mass. Cell tearing is probably caused by the formation of ice crystals. Fresh MPA sample contain more complete cells (Fig. 6a), which could give them

greater mechanical strength; this would justify that the values of the textural properties were higher in fresh MPA samples than in their processed counterparts. In turn, the processed MPA sample without added EVOO (Fig. 6c) developed a spongy appearance due to amylose and amylopectin retrogradation occurring during freezing and frozen storage (Ferrero *et al*. 1994).

The microphotograph of processed MPB sample without added EVOO (Fig. 6d) shows the presence of fibres or strands. According to Giannouli and Morris (2003), during freezing, XG chains are forced to align and associate by conversion of water to ice crystals. The forced associations survive upon thawing to give a cryogel network. It is likely that such strands are related to this XG conformational transition, since they were observed in most of the F/TMP containing cryoprotectants. Formation of strands can be explained by a progressive increase in local concentration of the polymer as liquid water is converted into ice crystals, promoting intermolecular associations.

Fig. 7 shows microphotographs of the counterparts of the samples shown in the Fig. 6, but with 50 g/kg added EVOO. When EVOO was added, a dispersed thin phase or layer of oil formed, enveloping all the microstructures constituting the MP. Fig. 7a shows some oil droplets in MPA sample, probably formed by aggregation through steric and/or electrostatic forces (Paraskevopoulou *et al*. 2005), whereas Fig. 7b shows no oil droplets in presence of $\kappa$-C and XG. In MPA samples, freezing also had a negative influence on the formation of oil droplet clusters (Fig. 7c); it is likely that the structural damage caused by freezing enabled the oil droplets to come close enough together to aggregate. Microphotograph of the processed sample with 50 g/kg added EVOO (Fig. 7d) shows that white gel structures are also discernible in the presence of cryoprotectants.

Addition of XG to salad dressings induces depletion flocculation of the droplets and formation of a three-dimensional weak gel network structure that retards the process of

droplet creaming (Parker *et al*. 1995). Adding a hydrocolloid causes protein-coated droplets to aggregate and be excluded from the region of continuous phase between them. Therefore, in the MP with added *κ*-C and XG and oil, the XG may have been adsorbed onto the surface of the droplets, enhancing stability against flocculation and coalescence and forming the white film observed in both microphotographs (Figs. 7b,d). On the other hand, there are no noticeable differences between FMP and F/TMP samples with added *κ*-C and XG and oil, confirming that the addition of *κ*-C and XG significantly reduced quality differences between FMP and their F/TMP counterparts.

## CONCLUSION

The addition of either EVOO or cryoprotectants and processing significantly affected the physical, structural and sensory characteristics of MP, although the effect of EVOO concentration depended on the presence of cryoprotectants and on freezing/thawing. Increased EVOO concentration resulted in less structured systems and enhancement of color due to an increase in overall light scattering and pigment content. Addition of *κ*-C and XG improved thickness, possibly through the exclusion effect of swollen starch granules promoting gelation of the *κ*-C. Addition of EVOO in increasing concentrations enhanced the sensory quality of MP in terms of reduced granularity, denseness, cohesiveness, adhesiveness and fibrousness, and increased homogeneity, ease of swallowing and palate coating. Instrumental texture measurements were able to distinguish the variations in mechanical textural attributes scored by the panellists. Conversely, geometrical textural attributes (granularity, homogeneity and fibrousness) have to be support by structural traits. Creaminess was the most crucial factor for OA of the products and could be explained by the presence of EVOO aggregates observed by microstructure

585 analysis. Samples with 50 g/kg added EVOO were judged the best of all. There is a
586 possibility of using EVOO in combination with MP to provide a highly nutritious product
587 with improved physicochemical, functional and sensory characteristics.
588

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698

**FIGURE LEGENDS**

FIG. 1. TEXTURAL PROPERTIES OF MASHED POTATOES WITH ADDED EXTRA VIRGIN OLIVE OIL (EVOO)

(A-C) Firmness; (D-F) Average force; MPA, MPB: mashed potatoes without and with added cryoprotectants respectively; FMP, F/TMP: fresh and frozen/thawed mashed potatoes respectively.

FIG. 2. COLOR PARAMETERS AND EXPRESSIBLE WATER OF MASHED POTATOES WITH ADDED EXTRA VIRGIN OLIVE OIL (EVOO)

(A-C) L*, lightness; a*, red-greeness; YI, yellowness index; (D) $E_w$, expressible water; MPA, MPB: mashed potatoes without and with added cryoprotectants respectively; FMP, F/TMP: fresh and frozen/thawed mashed potatoes respectively.

FIG. 3. TPA SENSORY ATTRIBUTES OF MASHED POTATOES WITH ADDED EXTRA VIRGIN OLIVE OIL (EVOO)

(A, B) Granularity; (C) Moisture (1); (D) Stickiness; (E, F) Denseness; (G, H) Homogeneity; (I) Moisture (2); MPA, MPB: mashed potatoes without and with added cryoprotectants respectively; FMP, F/TMP: fresh and frozen/thawed mashed potatoes respectively.

FIG. 4. TPA SENSORY ATTRIBUTES OF MASHED POTATOES WITH ADDED EXTRA VIRGIN OLIVE OIL (EVOO)

(A, B) Firmness; (C) Cohesiveness; (D, E) Adhesiveness; (F, G) Fibrousness (1); (H, I) Ease of swallowing; MPA, MPB: mashed potatoes without and with added cryoprotectants respectively; FMP, F/TMP: fresh and frozen/thawed mashed potatoes respectively.

FIG. 5. TPA SENSORY ATTRIBUTES AND OVERALL ACCEPTABILITY OF MASHED POTATOES WITH ADDED EXTRA VIRGIN OLIVE OIL (EVOO)

(A-C) Palate coating; (D) Fibrousness (2); (E, F) Overall acceptability (OA); MPA, MPB: mashed potatoes without and with added cryoprotectants respectively; FMP, F/TMP: fresh and frozen/thawed mashed potatoes respectively.

FIG. 6. MICROPHOTOGRAPHS OF MASHED POTATOES

(A) Fresh sample without added cryoprotectants; (B) Fresh sample with added cryoprotectants; (C) Processed sample without added cryoprotectants; (D) Processed sample with added cryoprotectants; Magnification was 200 (bar = 100 μm).

FIG. 7. MICROPHOTOGRAPHS OF MASHED POTATOES WITH ADDED EXTRA VIRGIN OLIVE OIL (EVOO)

(A) Fresh sample without added cryoprotectants and with 50 g/kg added EVOO; (B) Fresh sample with added cryoprotectants and with 50 g/kg added EVOO; (C) Processed sample without added cryoprotectants and with 50 g/kg added EVOO; (D) Processed sample with added cryoprotectants and with 50 g/kg added EVOO; Magnification was 200 (bar = 100 μm).

**FIGURE 1**

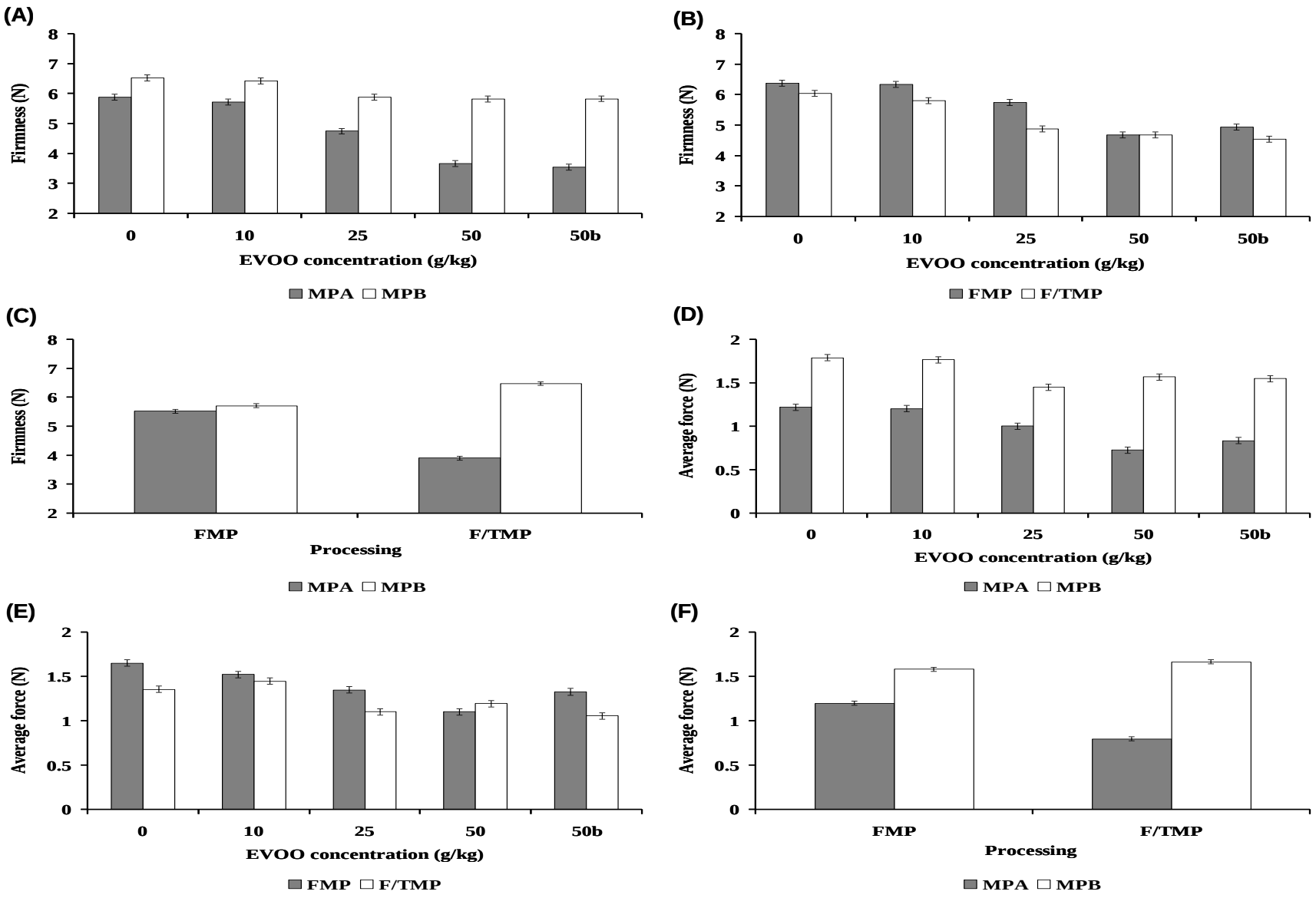

(A)
Firmness (N)
EVOO concentration (g/kg)
0
10
25
50
50b
MPA
MPB
(B)
Firmness (N)
EVOO concentration (g/kg)
FMP
F/TMP
(C)
Firmness (N)
FMP
F/TMP
Processing
MPA
MPB
(D)
Average force (N)
EVOO concentration (g/kg)
MPA
MPB
(E)
Average force (N)
EVOO concentration (g/kg)
FMP
F/TMP
(F)
Average force (N)
FMP
F/TMP
Processing
MPA
MPB

**FIGURE 2**

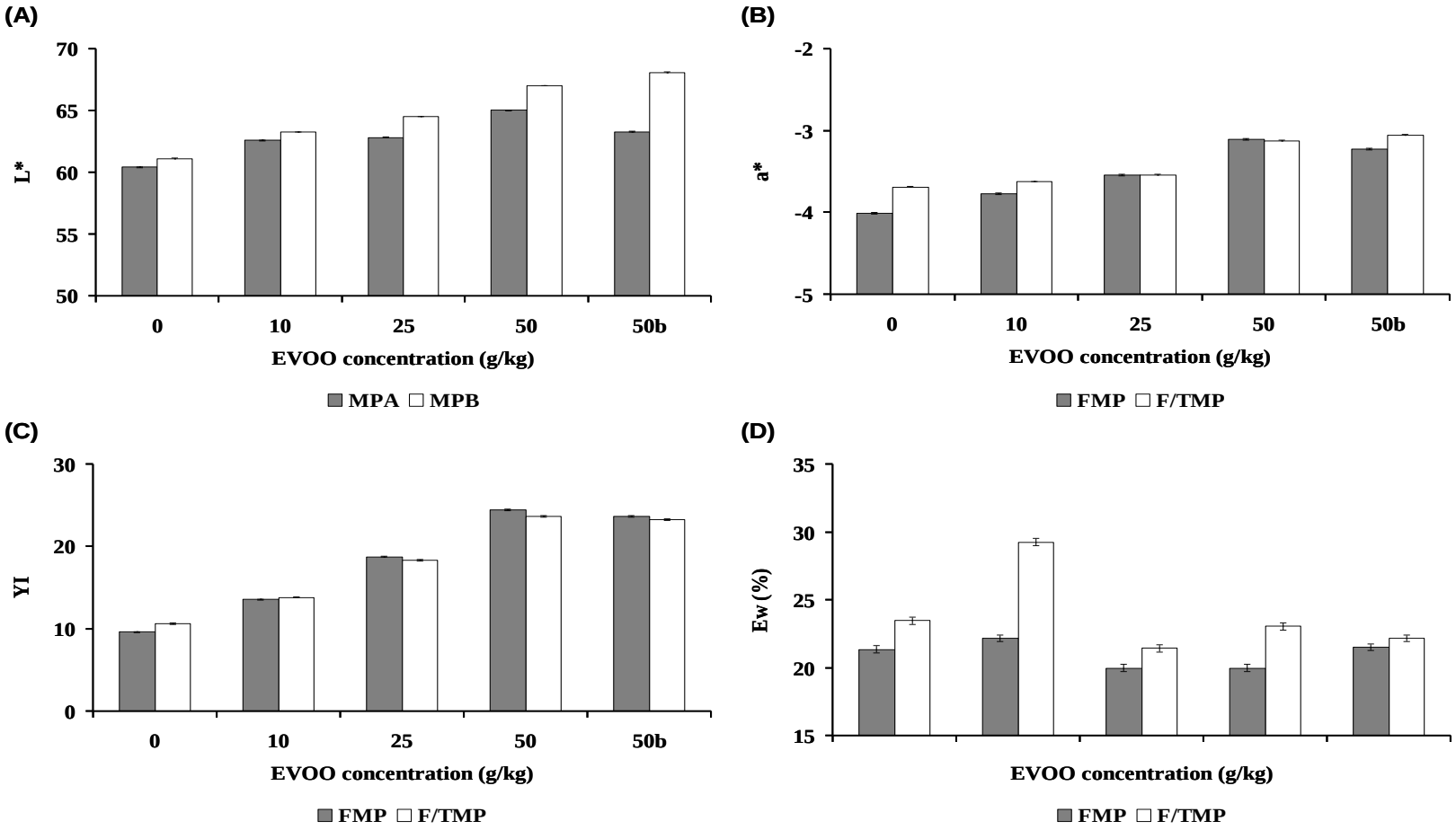

(A)
L*
70
65
60
55
50
0
10
25
50
50b
EVOO concentration (g/kg)
MPA
MPB
(B)
a*
-2
-3
-4
-5
0
10
25
50
50b
EVOO concentration (g/kg)
FMP
F/TMP
(C)
YI
30
20
10
0
0
10
25
50
50b
EVOO concentration (g/kg)
FMP
F/TMP
(D)
Ew (%)
35
30
25
20
15
EVOO concentration (g/kg)
FMP
F/TMP

**FIGURE 3**

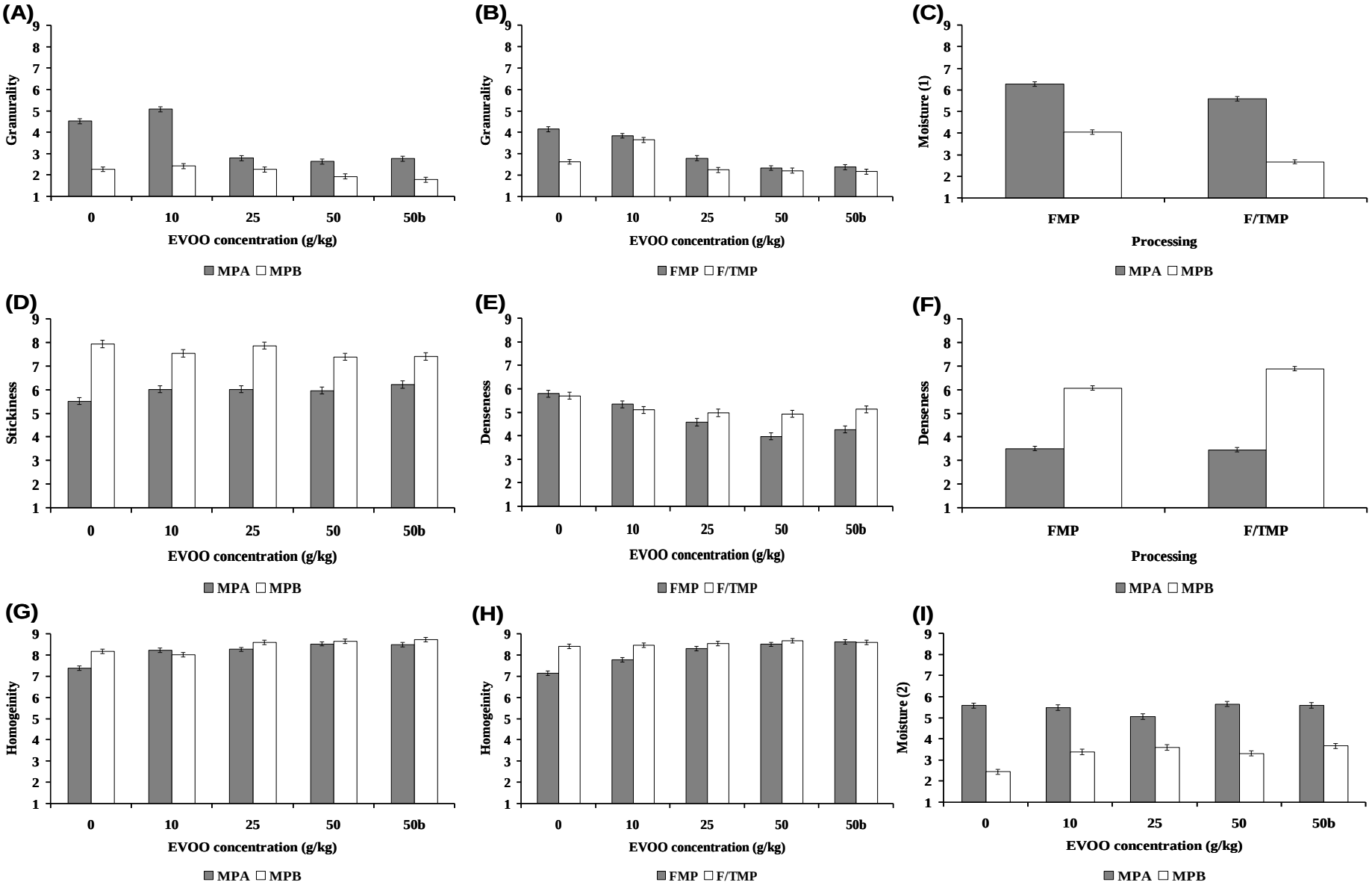

(A)
Granurality
EVOO concentration (g/kg)
0
10
25
50
50b
MPA
MPB
(B)
Granurality
EVOO concentration (g/kg)
FMP
F/TMP
(C)
Moisture (1)
FMP
F/TMP
Processing
MPA
MPB
(D)
Stickiness
EVOO concentration (g/kg)
MPA
MPB
(E)
Denseness
EVOO concentration (g/kg)
FMP
F/TMP
(F)
Denseness
FMP
F/TMP
Processing
MPA
MPB
(G)
Homogeinity
EVOO concentration (g/kg)
MPA
MPB
(H)
Homogeinity
EVOO concentration (g/kg)
FMP
F/TMP
(I)
Moisture (2)
EVOO concentration (g/kg)
MPA
MPB

**FIGURE 4**

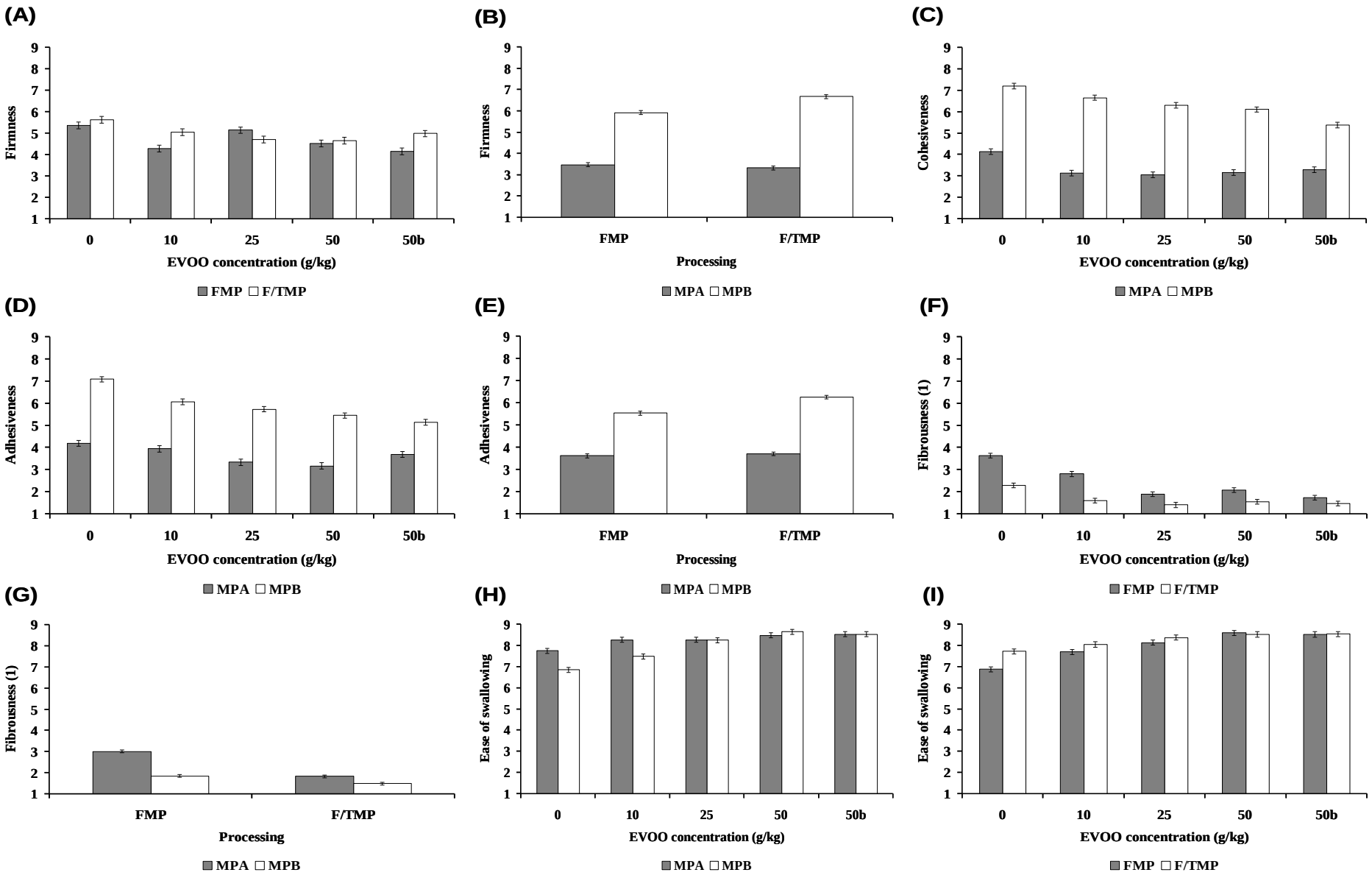

(A)
Firmness
EVOO concentration (g/kg)
0
10
25
50
50b
FMP
F/TMP
(B)
Firmness
Processing
FMP
F/TMP
MPA
MPB
(C)
Cohesiveness
EVOO concentration (g/kg)
MPA
MPB
(D)
Adhesiveness
EVOO concentration (g/kg)
MPA
MPB
(E)
Adhesiveness
Processing
(F)
Fibrousness (1)
EVOO concentration (g/kg)
FMP
F/TMP
(G)
Fibrousness (1)
Processing
(H)
Ease of swallowing
EVOO concentration (g/kg)
(I)
Ease of swallowing
EVOO concentration (g/kg)

**FIGURE 5**

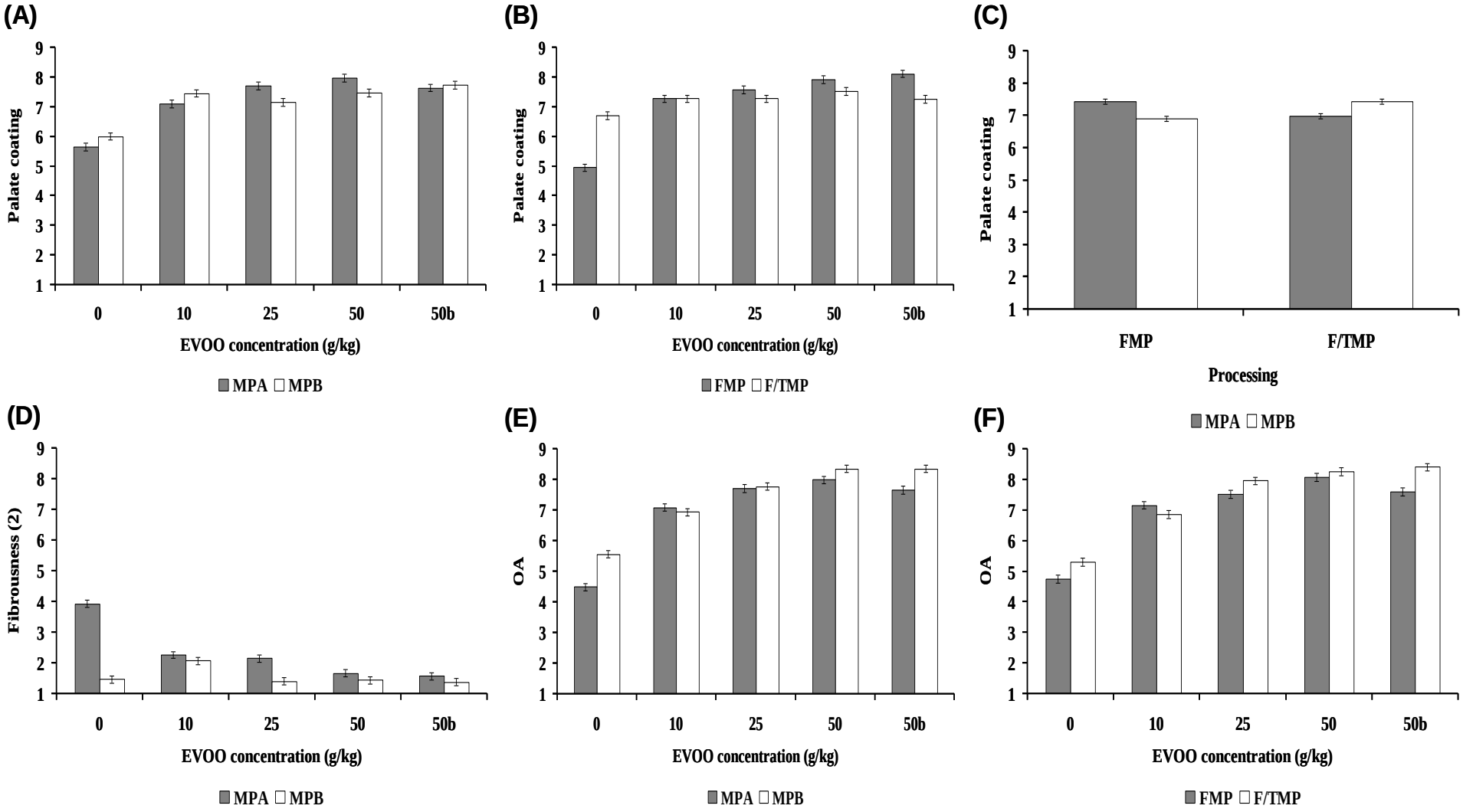

(A)
Palate coating
EVOO concentration (g/kg)
0
10
25
50
50b
MPA MPB
(B)
Palate coating
EVOO concentration (g/kg)
FMP F/TMP
(C)
Palate coating
FMP
F/TMP
Processing
(D)
Fibrousness (2)
EVOO concentration (g/kg)
MPA MPB
(E)
OA
EVOO concentration (g/kg)
MPA MPB
(F)
MPA MPB
OA
EVOO concentration (g/kg)
FMP F/TMP

**TABLE 1.** EFFECTS OF EVOO CONCENTRATION, CRYOPROTECTANT ADDITION AND FREEZING/THAWING ON TEXTURAL PROPERTIES OF MP

| Source | Firmness (N) | Viscosity index (N s) | Work per displaced volume ($J/m^3$) | Average force (N) |
|---|---|---|---|---|
| Main effects: | | | | |
| A:EVOO concentration (g/kg) | | | | |
| 0 | 6.21 a | -29.33 a | 3518.78 a | 1.51 a |
| 10 | 6.08 a | -28.37 a | 3462.25 a | 1.49 a |
| 25 | 5.32 b | -26.12 b | 2867.16 b | 1.23 b |
| 50 | 4.69 c | -23.06 c | 2681.10 b | 1.15 b |
| 50b | 4.74 c | -23.69 c | 2786.29 b | 1.19 b |
| *P* values | <0.001 | <0.001 | <0.001 | <0.001 |
| *LSD (99%)* | *0.26* | *1.24* | *227.00* | *0.097* |
| B:Cryoprotectant addition | | | | |
| Without $\kappa$-C and XG | 4.71 a | -20.71 a | 2333.51 a | 1.00 a |
| With $\kappa$-C and XG | 6.10 b | -31.52 b | 3792.72 b | 1.63 b |
| *P* values | <0.001 | <0.001 | <0.001 | <0.001 |
| *LSD (99%)* | *0.16* | *0.78* | *143.57* | *0.06* |
| C:Processing | | | | |
| Fresh | 5.62 a | -26.73 a | 3248.00 a | 1.39 a |
| Frozen/thawed | 5.19 b | -25.50 b | 2878.23 b | 1.23 b |
| *P* values | <0.001 | <0.001 | <0.001 | <0.001 |
| *LSD (99%)* | *0.16* | *0.78* | *143.57* | *0.06* |
| Interactions | | | | |
| AB | <0.001 | <0.001 | <0.001 | <0.001 |
| AC | 0.001 | 0.18 | <0.001 | <0.001 |
| BC | <0.001 | <0.001 | <0.001 | <0.001 |
| ABC | <0.001 | <0.001 | <0.001 | <0.001 |

**TABLE 2.** EFFECTS OF EVOO CONCENTRATION, CRYOPROTECTANT ADDITION AND FREEZING/THAWING ON COLOR MEASUREMENTS AND EXPRESSIBLE WATER OF MP

| Source | *L** | *a** | YI | $E_w$ (%) |
|---|---|---|---|---|
| Main effects: | | | | |
| A:EVOO concentration (g/kg) | | | | |
| 0 | 60.79 a | -3.85 a | 10.14 a | 22.42 b |
| 10 | 62.95 b | -3.70 b | 13.73 b | 25.73 a |
| 25 | 63.68 c | -3.54 c | 18.58 c | 20.72 d |
| 50 | 66.04 d | -3.11 d | 24.08 d | 21.52 c |
| 50b | 65.70 e | -3.14 d | 23.47 e | 21.85 b, c |
| *P* values | <0.001 | <0.001 | <0.001 | <0.001 |
| *LSD (99%)* | *0.07* | *0.02* | *0.20* | *0.71* |
| B:Cryoprotectant addition | | | | |
| Without *κ*-C and XG | 62.85 a | -3.59 a | 16.74 a | - |
| With *κ*-C and XG | 64.81 b | -3.34 b | 19.26 b | - |
| *P* values | <0.001 | <0.001 | <0.001 | - |
| *LSD (99%)* | *0.04* | *0.01* | *0.13* | - |
| C:Processing | | | | |
| Fresh | 63.33 a | -3.53 a | 18.03 a | 21.01 a |
| Frozen/thawed | 64.33 b | -3.40 b | 17.97 a | 23.89 b |
| *P* values | <0.001 | <0.001 | 0.17 | <0.001 |
| *LSD (99%)* | *0.04* | *0.01* | *0.13* | *0.45* |
| Interactions | | | | |
| AB | <0.001 | <0.001 | <0.001 | - |
| AC | <0.001 | <0.001 | <0.001 | <0.001 |
| BC | <0.001 | 0.34 | <0.001 | - |
| ABC | <0.001 | <0.001 | <0.001 | - |

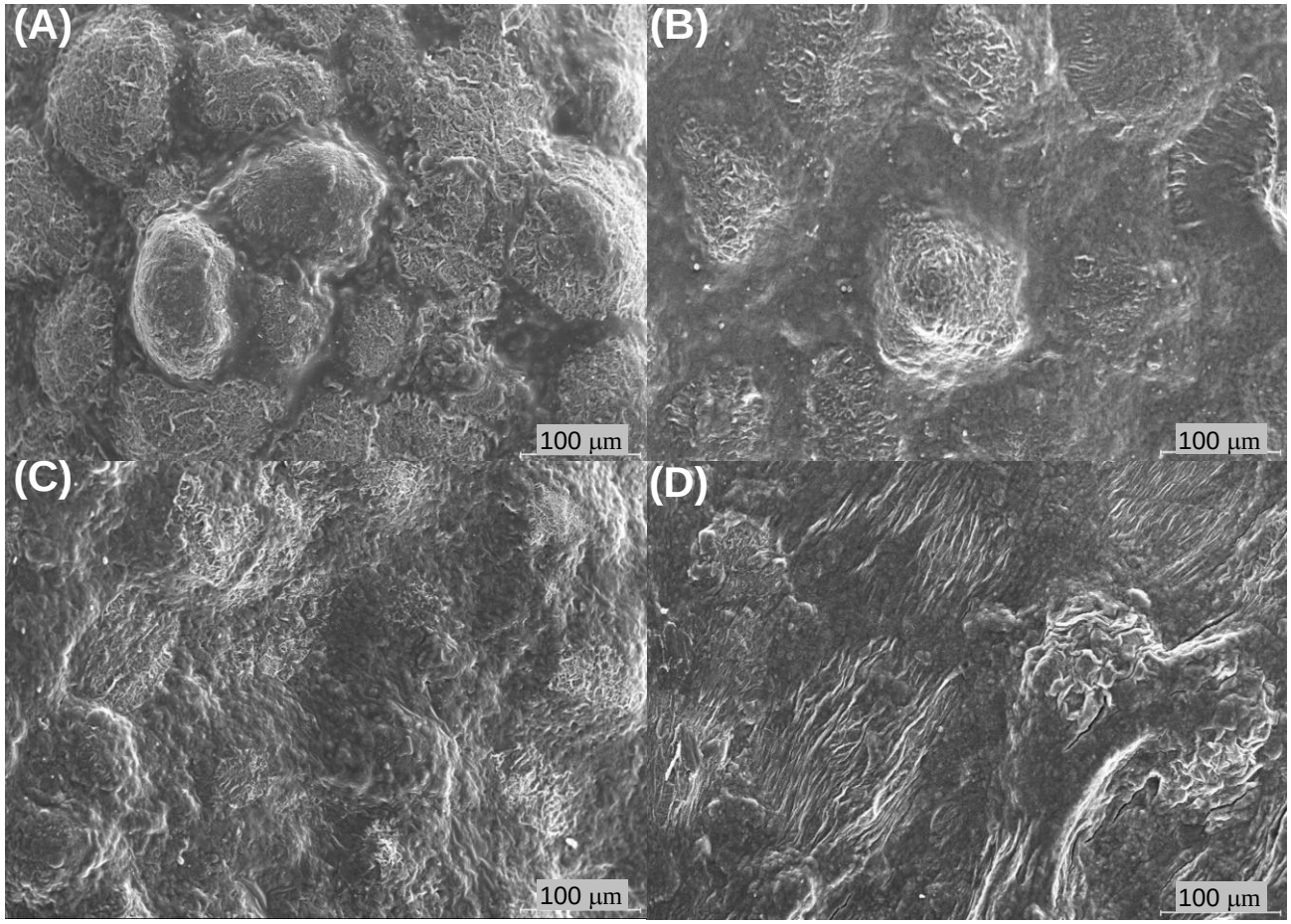
**TABLE 3.** EFFECTS OF EVOO CONCENTRATION, CRYOPROTECTANT ADDITION AND FREEZING/THAWING ON SENSORY ATTRIBUTES PERCEIVED BEFORE AND AT THE TIME OF PUTTING THE SAMPLE IN THE MOUTH, AND AT THE TIME OF PREPARING THE SAMPLE FOR SWALLOWING OF MP

| Sensory attributes | Perceived before putting the sample in the mouth | | Perceived at the time of putting the sample in the mouth | | | | | Perceived at the time of preparing the sample for swallowing | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source | Granularity | Moisture (1) | Stickiness | Denseness | Homogeneity | Moisture (2) | Firmness | Cohesiveness | Adhesiveness | Fibrousness (1) |
| Main effects: | | | | | | | | | | |
| A:EVOO concentration | <0.001 | 0.022 | 0.487 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| B:Cryoprotectant addition | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| C:Processing | <0.001 | <0.001 | 0.542 | <0.001 | <0.001 | <0.001 | 0.002 | 0.002 | <0.001 | <0.001 |
| Interactions | | | | | | | | | | |
| AB | <0.001 | 0.002 | 0.002 | 0.236 | <0.001 | <0.001 | 0.044 | <0.001 | <0.001 | <0.001 |
| AC | <0.001 | 0.003 | <0.001 | <0.001 | <0.001 | 0.082 | <0.001 | 0.292 | 0.818 | <0.001 |
| BC | 0.015 | 0.001 | 0.611 | <0.001 | 0.970 | 0.003 | <0.001 | 0.083 | <0.001 | <0.001 |
| ABC | <0.001 | <0.001 | <0.001 | 0.143 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

**TABLE 4.** EFFECTS OF EVOO CONCENTRATION, CRYOPROTECTANT ADDITION AND FREEZING/THAWING ON SENSORY ATTRIBUTES PERCEIVED DURING THE FINAL AND RESIDUAL PHASES OF MASTICATION AND OVERALL ACCEPTABILITY OF MP

| Sensory attributes | Perceived during the final and residual phases of mastication | | | Overall acceptability (OA) |
|---|---|---|---|---|
| Source | Ease of swallowing | Palate coating | Fibrousness (2) | |
| Main effects: | | | | |
| A:EVOO concentration | <0.001 | <0.001 | <0.001 | <0.001 |
| B:Cryoprotectant addition | <0.001 | 0.520 | <0.001 | <0.001 |
| C:Processing | <0.001 | 0.601 | <0.001 | <0.001 |
| Interactions | | | | |
| AB | <0.001 | <0.001 | <0.001 | <0.001 |
| AC | 0.003 | <0.001 | <0.001 | <0.001 |
| BC | 0.126 | <0.001 | <0.001 | 0.055 |
| ABC | 0.211 | <0.001 | <0.001 | 0.015 |

**FIGURE 6**



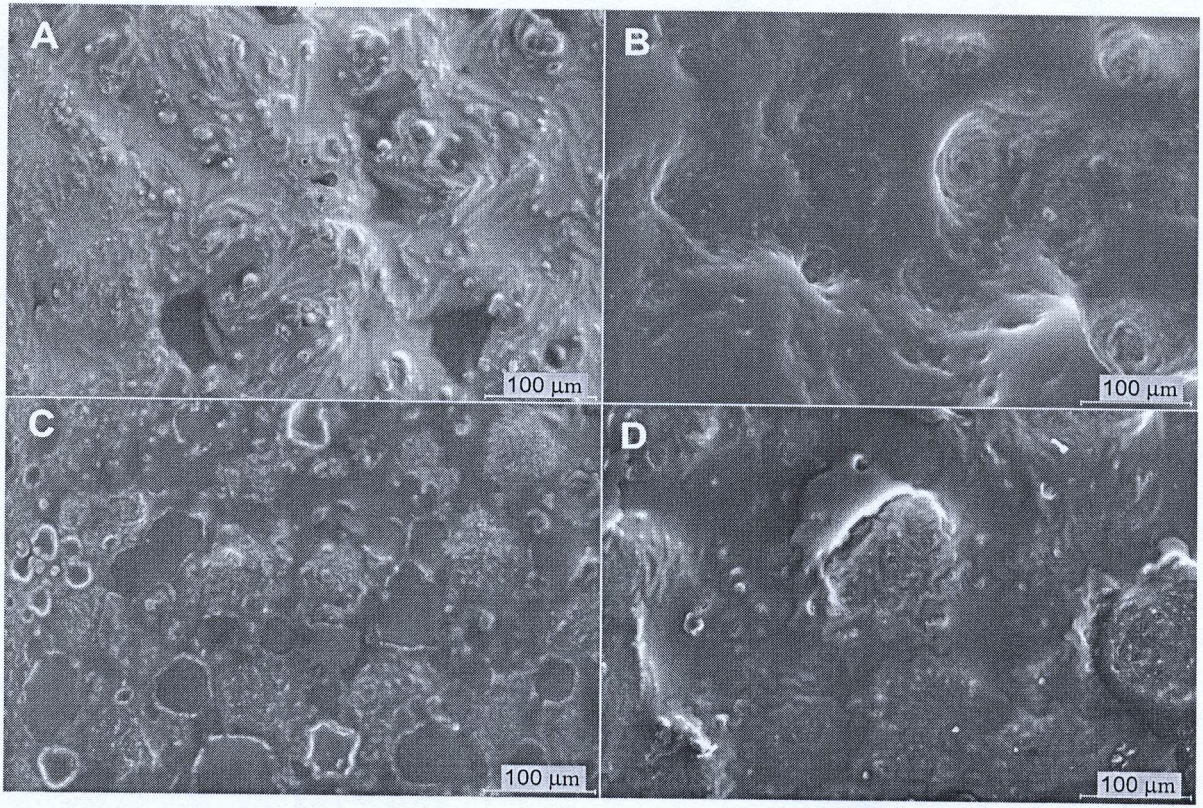



**FIG. 7.** MICROPHOTOGRAPHS OF MASHED POTATOES WITH ADDED EXTRA VIRGIN OLIVE OIL (EVOO)
(A) Fresh sample without added cryoprotectants and with 50 g/kg added EVOO; (B) Fresh sample with added cryoprotectants and with 50 g/kg added EVOO; (C) Processed sample without added cryoprotectants and with 50 g/kg added EVOO; (D) Processed sample with added cryoprotectants and with 50 g/kg added EVOO; Magnification was 200 (bar = 100 µm).