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Title: Characterization of food additives-potato starch complexes by FTIR and X-ray diffraction

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Abstract: Fourier Transform Infrared (FTIR) and X-ray diffraction (XRD) techniques were used to study the effect of four food additives agar, alginate, lecithin and glycerol; each added at three different concentrations 0.5, 1 and 1.5%, on the molecular structure of potato puree prepared from commercial potato powder. Vibrational spectra revealed that the amylose-amylopectin skeleton present in the raw potato starch, was missing in the potato powder, but can be fully recovered upon water addition when potato puree is prepared. FTIR peaks corresponding to water were clearly present in potato powder, indicating the important structural role of water molecules in the recovering of the initial molecular conformation.

None of the studied puree samples present a crystalline structure or strong internal order. Comparing FTIR and XRD results, it was found that additives exerted some effect mainly on the long-range order of the starch structure, via interacting and changing -OH and hydrogen bonds interactions.

December 5th 2017.

Dear Prof. Dr. P. Finglas (as Editor-in-chief of Food Chemistry journal),

On behalf of my colleagues and me, we would like you to consider for publication the following manuscript entitled:

“Characterization of food additives-potato starch complexes by FTIR and X-ray diffraction”

This is a new manuscript reporting some of our recent research progress in the study of the spectroscopical (FTIR and XRD) characterization of commercial starch and modified commercial starch by using different additives, to improve its usage in food technologies.

In our opinion, these results contribute to the knowledge of the effect that food additives can have on the starch, its structure and stability, given also information about the mechanism involved in the starch microstructure changes.

The work described in this paper has not been published before, and it is not under consideration for publication anywhere else.

We hope our manuscript is suitable for publication in Food Chemistry journal

Yours sincerely,

Dr. Francesc Sepulcre

Highlights

1. Starch skeleton is missing in the dehydrated commercial starch, but can be recovered adding water
2. Additives interact with starch at molecular level disrupting OH bonds altering its conformation
3. Water molecules have an important structural role on the maintenance of the starch structure
4. Potato starch has a XRD pattern compatible with the presence of V-type structure
5. FTIR peak centred at 2100 cm^{-1} can be assigned to free water in starch

1 Characterization of food additives-potato starch complexes by FTIR and X-ray diffraction

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16 **Abstract**

17

18 Fourier Transform Infrared (FTIR) and X-ray diffraction (XRD) techniques were used to study the effect
19 of four food additives agar, alginate, lecithin and glycerol; each added at three different concentrations
20 0.5, 1 and 1.5%, on the molecular structure of potato pure prepared from commercial potato powder.

21 Vibrational spectra revealed that the amylose-amylopectin skeleton present in the raw potato starch, was
22 missing in the potato powder, but can be fully recovered upon water addition when potato puree is
23 prepared. FTIR peaks corresponding to water were clearly present in potato powder, indicating the
24 important structural role of water molecules in the recovering of the initial molecular conformation.

25 None of the studied puree samples present a crystalline structure or strong internal order. Comparing
26 FTIR and XRD results, it was found that additives exerted some effect mainly on the long-range order of
27 the starch structure, via interacting and changing -OH and hydrogen bonds interactions.

28

29 **1. Introduction**

30 Recently, modified starches have gained priority in the gastronomic field due to their enhanced functional
31 properties compared to unmodified starches (Perera, Hoover, & Martin, 1997; Sun, Si, Xiang & Chu,
32 2013). Processing starch with different types of food additives promotes a wider range of variation in its
33 chemical, mechanical and sensorial characteristics and thus stimulates a broader array of its functional
34 applicability. In fact, these modification practices applied during food processing leads to the formation
35 or absence of certain molecular structures because of the interactions among molecular components of the
36 ingredients. Subsequently, modulating important physiochemical, mechanical and organoleptic properties
37 of food (BeMiller, 2011; Chaisawang & Suphantharika, 2005; Fu et al., 2015; Singh, Kaur, & McCarthy,
38 2007; Stephen, 1995). Therefore, while developing new food products, it is important to take into
39 consideration all the possible interactions among molecular ingredients and to examine these interactions
40 at the structural level such as to develop a better understanding and ensure an integrated linking between
41 structural properties and food texture. Consequently, this will permit food scientists and technologists to
42 gain the keys for an overall control, modulations and improvements of food properties that will meet the
43 perceptions and desires of consumers.

44 Generally, the raw starch found in potato tubers is organized into structurally void granules consisting of
45 two types of α -glucans: amylopectin (a heavily branched α -glucan polymer of high average molecular
46 weight with an α (1 \rightarrow 4) linked backbone and α (1 \rightarrow 6) linked branches) and amylose (a linear and relative
47 long α -glucan polymer linked by α (1 \rightarrow 4) linkages). Raw starch granules show a crystalline/amorphous
48 structure that can be recognized at both short (nm) and long-range (several μ m) scales. In particular, short
49 range ordering corresponds to double and single helical of amylose or amylopectin embedded in
50 amorphous or crystalline lamellar regions, as well as amylose-amylopectin helices complexes (Tester,
51 Karkalas, & Qi, 2004). The arrangement and ordering of double helices into concentric alternating stacks
52 of microcrystalline and amorphous lamellar structures is associated with long range ordering.

53 Moreover, these raw starch microstructures and conformations change upon industrial treatments, which
54 generally include heating and/or change in the amount of the absorbed water, varying its
55 crystalline/amorphous regions ratio, its susceptibility to enzymatic hydrolysis, texture, and/or sensorial or
56 rheological properties, among others.

57 Several techniques have been used in numerous starches and modified starch studies by different authors
58 in order to characterize the molecular interactions that are responsible for the short and long-range

59 organizations (Liu et al., 2011). Using Fourier Transform Infrared Spectroscopy (FTIR), the most
60 characteristic vibrational bands of several starches have been assigned providing information on amylose
61 and amylopectin chain folding (Kizil, Joseph Irudayaraj, & Seetharaman, 2002) and the
62 crystalline/amorphous ratio (Ispas-Szabo et al., 1999). Retro-gradation of potato starch has been also
63 studied by FTIR (Flores-Molares et al., 2012; Van Soest et al., 1994) concluding that the spectral region
64 800-1100 cm^{-1} contains bands that are sensitive to starch polymer conformation (α (1 \rightarrow 4) linked
65 backbone, -CH₂ backbone...). This spectral region can be used to follow crystallite melting and the
66 multi-stage processes of retro-gradation (Flores-Molares et al., 2012; Zhang et al., 2013). Several works
67 affirm that the ratio between the absorbance intensity of bands located at 1047 and 1022 cm^{-1} could be
68 used to quantify the index of crystallinity because these bands can be associated to ordered and
69 amorphous structure respectively (Flores-Molares et al., 2012).

70 Additionally, X-ray diffraction (XRD) is another important tool that has been used to characterize starch
71 structure and to detect any changes in the starch pattern crystallinity because of different processing
72 techniques. For example, Ribotta et al. (2004) found that amylopectin retro-gradation and B-type
73 crystalline structure augmented during ageing by using DCS and XRD, and Liu et al. (2002) studied
74 thermal phase transitions in potato starch-water systems.

75 In a previous work (Dankar et al., 2018) we investigated, the effect that four food additives (agar,
76 glycerol, alginate and lecithin) at different concentrations induced on the rheological properties of potato
77 puree prepared from commercial potato flakes. The results found were strongly concentration dependent
78 such as at higher concentrations agar and alginate elevated the viscosity and yield stress of potato puree
79 whereas glycerol and lecithin had diminished them and produced products that are more unstable.
80 Accordingly, the present work aims to contribute to the knowledge of the effect that these additives had
81 exerted on the structural molecular level of potato starch and its induced conformational changes, by
82 collecting the respective FTIR spectra (short-term order) and XRD patterns (long-term order) of potato
83 puree and potato puree samples containing additives and trying to correlate between them.

84 **2. Materials and Methods**

85 *2.1. Sample preparation*

86 Dehydrated potato puree (Maggi, origin) and whole milk were purchased from the local
87 supermarket. Agar-agar, Soy Bean lecithin, sodium alginate and glycerol (food grade) were procured
88 from Sigma-Aldrich Co. Potato puree samples were prepared according to the following ratio (90mL

89 milk and 10 mL water heated previously to 40°C and then 23g of potato powder were added). The
90 mixture was then homogenized for 3 minutes using an electrical hand blender (Braun, Germany). The
91 same procedure was followed for preparing the puree samples with the four different additives at
92 three different concentrations 0.5, 1 and 1.5%. Additives with their corresponding percentage were
93 added and dissolved in the warmed solution (milk and water) prior to the incorporation of the potato
94 powder. However, for agar, solutions were boiled to 100°C and dehydrated potato was then added.
95 Subsequently, all samples were set in an incubator until they maintain a temperature of 20 °C
96 preceding the chemical analysis. Moreover, in order to compare between the structure of commercial
97 potato powder and native potato, a small fraction of raw potato was taken from the middle of a tuber,
98 grinded and applied to FTIR chemical analysis.

99 2.2 Chemical analysis

100 2.2.1 FTIR:

101 FTIR spectra were done for all additives, potato powder, potato puree and their mixture
102 (alone and with the different concentrations of additives) as well as the FTIR spectrum of raw
103 potato alone on STS FTIR spectrometer. Spectrum was recorded in the range of wavenumber
104 from 349 to 4000 /cm⁻¹ by an MCT detector cooled with liquid nitrogen. The samples were
105 blended with KBr and pressed into tablets before measurements. Spectra were collected at a
106 resolution of 4 cm⁻¹ and at an average of 35 number of scans per sample.

107 2.2.2 X-ray Diffraction:

108 XRD patterns of potato puree and the mixtures (potato puree alone and with the different
109 concentrations of additives) were carried out using an X-ray diffractometer (Bruker D8 Discover
110 AXS GmbH, Germany) equipped with Cu Radiation at wavelength of 1.5406 Å. Measurements
111 were obtained at room temperature with a scanning rate of 0.02°/1s and a diffraction angle range
112 of 5 to 80° (2-Theta° range), where theta is the angle of incidence of the x-ray beam on the
113 sample. The diffraction patterns were analyzed using EVA software.

114 3. Results and Discussion

115 3.1 Fourier transforms Infrared Spectroscopy

116 Comparison between commercial potato powder, potato puree and potato starch

117 For clarity, we divided the IR spectra in two regions: from 4000 to 1500 cm⁻¹ and from 1500 to 400 cm⁻¹.

118 Spectral region from 4000 to 1500 cm⁻¹

119 Figure 1 shows the IR of commercial starch powder, potato puree prepared from the commercial starch
120 powder, and raw potato. All these three samples showed the same characteristic peaks at 3500 cm⁻¹, 2900
121 cm⁻¹, 2100 cm⁻¹ and 1650 cm⁻¹. Peak at 1642 cm⁻¹ has been assigned to water molecules absorbed in the
122 amorphous region (Kizil, Joseph Irudayaraj, & Seetharaman, 2002) and also to stretching vibration of
123 C=O band (amide I). Peak at 2100 cm⁻¹ originates for the free water content (Olsson & Salmén, 2004),
124 and peaks at 2900 and 3500 cm⁻¹ are due to the CH₂ deformation and OH bond respectively (Kačuráková
125 & Mathlouthi, 1996).

126 The dehydrated sample (commercial potato powder), except for the peak at 2100 cm⁻¹ (corresponding for
127 the free water content), presented also the same peak characteristics assigned to the hydrated samples
128 (commercial potato powder and potato starch) but with less intensity (Fig. 1). This indicates that even
129 dehydrated, starch keeps some water molecules strongly bound to some starch chemical groups via OH
130 bonds, probably because these water molecules have some structural role. Peak centered at about 2100
131 cm⁻¹ has not been assigned yet for starch, but Olsson & Salmén. (2004) found that its IR intensity
132 increased in a sample of kraft paper when absorbed water increases, being assigned in consequence to
133 vibrations from the scission and rocking of water. In our case the intensity of this peak increased when
134 water was added to prepare potato puree from potato powder (dehydrated starch) (Fig. 1), and therefore,
135 in agreement with Olsson & Salmén (2004), we assign it to free water molecules that are not directly
136 bound to starch.

137 Spectral region from 1500 to 400 cm⁻¹

138 The most important structural differences among these three samples can be observed in the region from
139 1500 to 400 cm⁻¹ (Fig. 1). Changes in the bands located in this region provided information about changes
140 in the polymeric structure and conformation of starch and it is considered the finger print region.
141 Characteristic peaks of potato starch have been previously described by several authors: 1412 cm⁻¹
142 assigned to -CH₂ bending and -COO stretch (Cael, Gardner, Koenig, & Blackwell, 1975; Ramazan Kizil
143 et al., 2002); 1048 cm⁻¹ and 1022 cm⁻¹ assigned to the crystalline and amorphous region of starch
144 respectively (Kačuráková & Mathlouthi, 1996); 1164 cm⁻¹ assigned to vibrations of the glucosidic C-O-C
145 bond as well as that of the whole glucose ring that can be present actually at different modes of vibrations
146 and bending conformations. Bond at 930 cm⁻¹, assigned to the skeletal mode vibrations of α 1→4 skeletal
147 glycoside bonds (JAO & KO, 2002), 780 cm⁻¹ assigned to C-C stretch (Sekkal, Dincq, Legrandb, &

148 Huvenne, 1995) and 577 cm^{-1} assigned to skeletal modes of pyranose ring (Cael et al., 1975). Comparing
149 the three samples together it was spotted that raw potato and potato puree expressed similar peaks but
150 with small differences in intensity, in which the peaks expressed by potato puree are of slightly higher
151 intensity than that of raw potato. Whereas the commercial potato powder expressed relatively small
152 intensity vibrations, indicating somehow the disappearance of a definitive internal structure for the potato
153 powder nevertheless that was regenerated upon the addition of water and the preparation of potato puree.

154 Moreover, while comparing between the FTIR spectra of raw and dehydrated starches, the processing
155 effect or temperature effect can be distinguished by the shifting of similar peaks towards a slightly higher
156 or lower wavenumber, for example glycosidic bond located in the spectrum of native starch at 1150 cm^{-1} ,
157 after heating shifted to 1170 cm^{-1} , skeletal modes of pyranose ring originally at 717 cm^{-1} wavenumber
158 moved to 615 cm^{-1} in dehydrated flakes. This effect was also stated by Siemion et al. (2004) who studied
159 the effect of temperature on native starches. However, after adding water to potato flakes, the spectrum of
160 potato puree and raw potato starch resembled so much each other (only small difference in intensity
161 levels as stated above). Even the small peaks and vibrations that appeared in the potato powder spectrum
162 between (900 and 500 cm^{-1}) disappeared, and again this proves the importance of water in maintaining
163 the whole structure of starch, as if it surpasses the effect that the temperature had already exerted on
164 dehydrated flakes. Evidently, this suggests that potato starch that had been previously dehydrated can
165 recover almost its original internal structure, by adding water. Perhaps, water molecules that are strongly
166 bound to starch and that are present even in the dehydrated sample, have an important structural role, and
167 help to recover partially the internal starch structure when its rehydrated.

168 Furthermore, relative intensity between peaks at 1022 and 1048 cm^{-1} has been used to characterize the
169 content of the crystalline starch, because these two peaks have been respectively assigned to amorphous
170 and crystalline starch (Sevenou, Hill, Farhat, & Mitchell, 2002). In the case of the raw potato and potato
171 puree samples, peaks at 1022 cm^{-1} were relatively higher in intensity with respect to those at 1048 cm^{-1} .
172 Thus, a more amorphous starch conformation rather than crystalline exists in the structure of potatoes. In
173 a good agreement with this result, a high intensity band located at 1642 cm^{-1} (assigned to water molecules
174 absorbed in the amorphous region) was also expressed in the potato puree and raw potato spectra.

175 Additionally, important differences were also observed in the vibrational region from 930 to 500 cm^{-1} ,
176 which have been assigned to the “secondary starch structure” mainly originated by vibrations of the

177 skeletal mode of α (1 \rightarrow 4) glycosidic linkage, skeletal modes of C-C stretch and the skeletal modes of the
178 pyranose ring (Fan et al., 2012). Whereas raw potato showed intense and narrow peaks at these normal
179 mode vibrations, potato puree showed an intense but smoothed band 900 to 400 cm^{-1} , suggesting an
180 increase in the number of the α -glucan polymers conformations, and therefore a decrease in the helical
181 content/skeletal mode vibration of α linkage/backbone of $-\text{CH}_2-\text{CH}_2-$ bending vibrations and/or pyranose
182 ring, which consequently leads also to a decrease in the long range ordering.

183 **Adding additives**

184 FTIR spectra of commercial potato puree and potato pure containing the different additives at different
185 concentrations were all of them similar in shape, but not in intensity (Fig. 2), indicating that additives
186 have some effect mainly on the long-range ordering and crystallinity.

187 Lecithin is the only additive that at both concentrations of 0.5 and 1% increased IR intensity of the peaks
188 centered at 1020 cm^{-1} , 1412 cm^{-1} and 2900 cm^{-1} (Fig. 2a,c). Peaks at 1412 and 2900 cm^{-1} were assigned to
189 the $-\text{CH}_2$ bending / $-\text{COOH}$ stretch, and $-\text{CH}_2$ stretching respectively (Fan et al., 2012). In comparison
190 with the other additives, lecithin possesses a high number of $-\text{CH}_2$ groups that can be responsible for this
191 increase. Therefore, in this case what is observed mostly is the contribution of these lecithin methyl
192 groups rather than a starch-additive interaction.

193 Moreover, except lecithin, all the other additives studied here decreased the IR intensity of the potato
194 puree sample in all the spectral range (4000 to 400 cm^{-1}). The three characteristics peaks related with
195 water content (3500, 2100 and 1642 cm^{-1}) are all decreased in intensity when additives were added to
196 potato puree. Change in the intensity at 3500 cm^{-1} , can be related with some rearranging of hydrogen
197 bonds between starch $-\text{OH}$ groups and some groups from additive molecules, more than a change with
198 water content. A similar interpretation can be done for peaks centered at 2100 cm^{-1} (free water) and at
199 1642 cm^{-1} (water molecules absorbed in the amorphous region) in terms of additives interaction with
200 water molecules initially bound to starch chemical groups. Diminution of these two peaks are indicatives
201 of a movement/sequestration of several water molecules from starch, inducing a decrease of the water
202 content in the amorphous part of starch, as well as of water molecules that are not directly bound to
203 starch.

204 Furthermore, changes in the intensity of the IR bands assigned to structural motives of starch
205 (characteristics peaks at 2900, 1412, 1022, 930 and 570 cm^{-1}) can be interpreted as a loss of the
206 polymeric starch secondary structure, as for example changes in amylose and/or amylopectin helix
207 content, or a loss in the α (1 \rightarrow 4) and α (1 \rightarrow 6) linked backbone conformation, as the result of starch-
208 additive granule interaction either directly by entering and rupturing the starch granule or indirectly by
209 holding and retarding water penetration inside starch granules. Therefore, in both mentioned cases
210 inducing conformational changes to starch molecules (Dankar et al., 2018).

211 At an additive concentration of 0.5%, a change in the IR intensity of region 1000 to 400 cm^{-1} was
212 observed with respect to that of potato puree (Fig. 2a). Glycerol and lecithin were the additives that
213 decreased the IR intensity of potato puree at this corresponding range the most. Most probably, due to
214 their smaller molecular sizes that they possess in comparison to agar and alginate. Which in turn
215 facilitates their penetration entirely into the starch granule, and allows their direct interaction with the
216 starch OH groups. Consequently, altering the α (1 \rightarrow 4) linked backbone of the potato starch components.
217 On the other hand, the relatively long and big molecular sizes expressed by agar and alginate, retarded
218 their penetration into the starch granule. So, the kind of interaction between these two additives and starch
219 molecule would be more constrained to the OH groups located on the granule surface which permits the
220 partial maintenance of the integrity of the starch granules which means the conformation of amylose and
221 amylopectin. This effect was reflected through the FTIR spectra in recording little differences between
222 the intensities of puree with agar and alginate and that of puree alone within the 1000-400 cm^{-1} region,
223 this region that is a reflection of any conformational changes in the starch structure as stated above.

224 When additives concentration increased from 0.5 to 1% the IR intensity of the potato purees containing
225 glycerol, alginate and agar clearly decreased (Fig. 2a,c), indicating a total loss of the secondary structure
226 (helical content) and the α -glucan backbone polymeric conformation, as a consequence of the interaction
227 between additives and starch. A further increase of the additive concentration from 1% to 1.5% increase
228 the IR intensity for all the samples, excepting for potato puree containing alginate (Fig. 2c). This increase
229 in the IR intensity can be explained by the formation of additives' aggregates and/or networks among the
230 additive molecules, due to their high concentration (1.5%) rather than the interaction between additives
231 and starch.

232 Hence, the FTIR results corroborate to the imperative role that water molecules exert on the starch
233 structure, in agreement with several authors (Blazek & Gilbert, 2011; Dankar, Haddarah, El Omar,
234 Sepulcre, & Pujolà, 2018; Liu et al., 2002). The ability of dehydrated starch to recover almost totally its
235 short and long level structures (regain back its original structure) upon the addition of water was also
236 established.

237 In this sense, it was clear the inter-dependence and reliance between peaks corresponding to water content
238 and those that are originated by the polymeric conformation of starch and the skeleton (secondary
239 structure).

240 **3.2 X-ray Diffraction**

241 Figure 3 shows XRD patterns of potato puree and potato puree containing additives. Potato puree
242 displayed a diffraction pattern very different from that of potato starch as reported by Lopez-Rubio et al.
243 (2008). Potato puree presented a unique broad peak centered at about 26° . Likewise, a similar diffraction
244 pattern was recorded by Ribotta et al. (2004) for bread; Yadav et al. (2006) for dried potato starch; Ispas-
245 Szabo et al. (1999) for cross-linked-high amylose starch and Liu et al. (2002) for potato starch-water
246 systems. In all these cited references, the XRD pattern of starch has been related to a V-type starch
247 structure that appeared as a unique broad band centered at about 20° , indicating that the crystal lattice has
248 become irregular or amorphous, due to the different physical and/or chemical treatments applied in each
249 case. Accordingly, the peak found at 26° could be interpreted as a small change of the V-type structure
250 (mainly a change in d-spacing). In fact, Potato puree, that was prepared from commercial potato flakes, is
251 driven from potato starch that has been previously dehydrated (heated approximately to 60 C°) and
252 rehydrated. It is well known that all these treatments alter the starch conformation, decreasing the amount
253 of crystalline starch (responsible for the narrow XRD peaks in the potato starch), and increasing in
254 consequence, the amount of the amorphous lamellar region. Thus, prompting its appearance as a broad
255 and weak intense band.

256 Figure 3a shows the x-ray diffraction patterns of potato puree with additives at 0.5% concentration. In all
257 the cases, the same broad and weak peak was observed. These diffraction patterns can be explained by the
258 presence of an amorphous starch with some internal order at a short-range level, such as a different
259 helical content.

260 Although diffraction patterns from the different purees containing additives revealed the absence of a
261 strong internal ordered structure, some interesting changes at the long-order range can be spotted. At
262 0.5% concentration (Fig. 3a), all the additives decreased the maximum 2θ angle (i.e. increase d-spacing),
263 followed by a decrease in intensity: potato>alginate>agar>glycerol>lecithin.

264 Furthermore, an increase in the additives concentration (from 0.5% to 1.0 %, (Fig. 3 a,b) produced a
265 decrease in the intensity for agar, alginate and glycerol. In fact, the intensity of the XRD spectrum of
266 potato puree containing glycerol showed a tendency towards zero. On the other hand, lecithin revealed an
267 opposite tendency of an increase in the intensity of the XRD spectrum as compared to potato puree (Fig.
268 3b).

269 The submissive and obliterating effect induced upon the addition of glycerol on the XRD intensity of
270 potato puree was more evidenced when glycerol concentration increased (Fig. 3b, c). This corroborates
271 that glycerol has a more direct interaction with starch than the other additives, probably entering into the
272 starch granule and destroying it as proposed previously (Dankar et al. 2018) and in agreement with the
273 FTIR results.

274 Besides, agar additive produced a monotonous decrease in the intensity of the diffraction pattern as its
275 concentration increased. Whereas in the case of alginate and lecithin, a first decrease in the intensity
276 followed by an increase was observed when the additives concentration increased to 1.5% (Fig. 3b, c).
277 These results can be explained by the fact that what controls the rate of crystallization and the sharpness
278 of the XRD pattern is the water content available in the molecule (Van Soest & Vliegenthart, 1997). As
279 previously experimented (Dankar et al., 2018), the effect of additives on the microstructure of potato
280 starch, it was suggested that lecithin facilitates the penetration of water inside the starch molecules. Thus,
281 rendering more their availability for maintaining structure and inducing a more ordered assembly, which
282 is revealed by the higher peak expressed with lecithin addition at higher concentrations. Conversely, the
283 addition of agar sequesters the water molecules and induces a transversal cross linking between the
284 polysaccharide chains which in turn alters swelling and hinders achieving a favorable conformation and
285 therefore the structure remained almost un-ordered which was revealed in the decrease of the intensity
286 value of the XRD peaks for puree with agar.

287

288 **4. Conclusions**

289 The effect of food additives on the molecular structure of potato puree prepared from commercial potato
290 powder was investigated. Using FTIR it was found that the skeleton formed by amylase and/or
291 amylopectin is somehow hidden in the dehydrated commercial potato flakes, but can be recovered by
292 adding water to a high degree of resemblance to that of the original raw potato starch structure. Although
293 the skeleton of amylase and/or amylopectin is missing in the dehydrated commercial starch, this sample
294 kept an important amount of water, as can be deduced by the intensity of the FTIR peaks, that actually
295 had some role in the recovering of the structure. Therefore, water molecules have a central chief role in
296 the maintenance of the starch structural conformation.

297 Although potato puree has mainly an amorphous starch (had lost crystallinity), its XRD pattern is
298 compatible with the presence of V-type starch structure.

299 Additives interact with starch at molecular level disrupting the OH bonds and altering the starch
300 conformation. Small molecules as glycerol and lecithin can enter into the starch granules and induce a
301 more intensive effect on the structure as their respective concentrations increase either by suppressing the
302 starch structure such as the effect exerted by glycerol or by stimulating a more ordered one upon the
303 addition of lecithin. Whereas long polymeric molecules as agar and alginate interact partially via the
304 surface of the starch granules or with just one part of the starch, and thus exert partial modifications to the
305 conformation of potato starch structure.

306

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Figure 1
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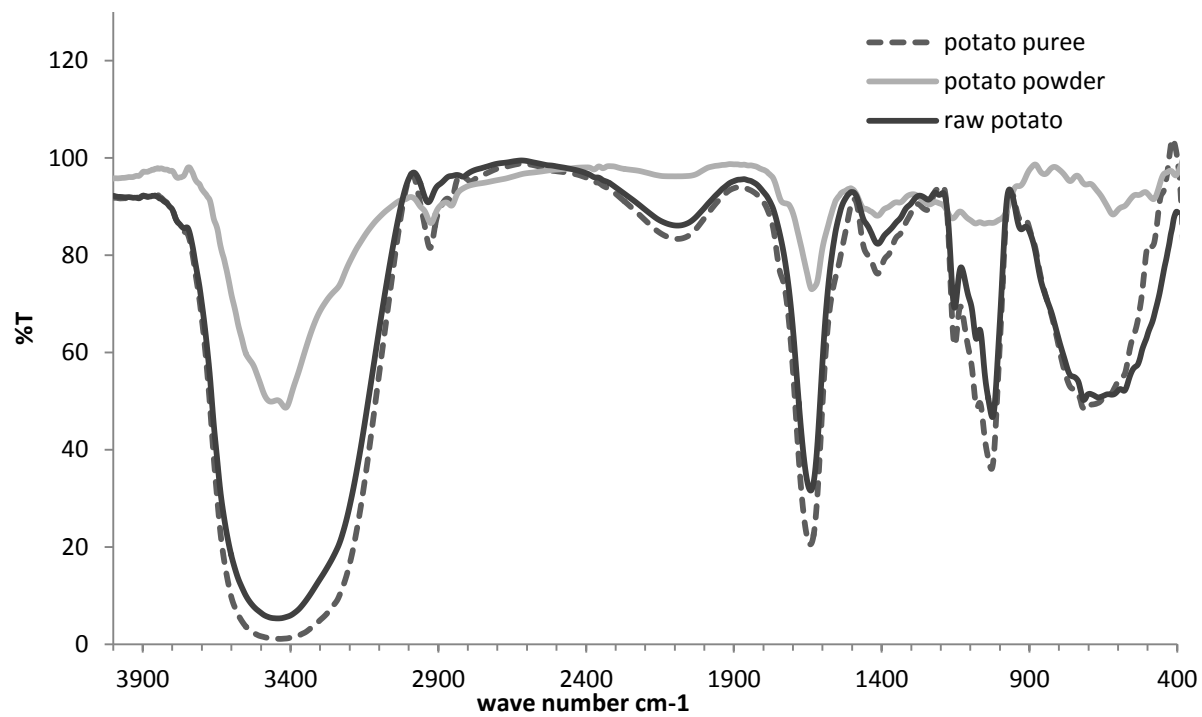
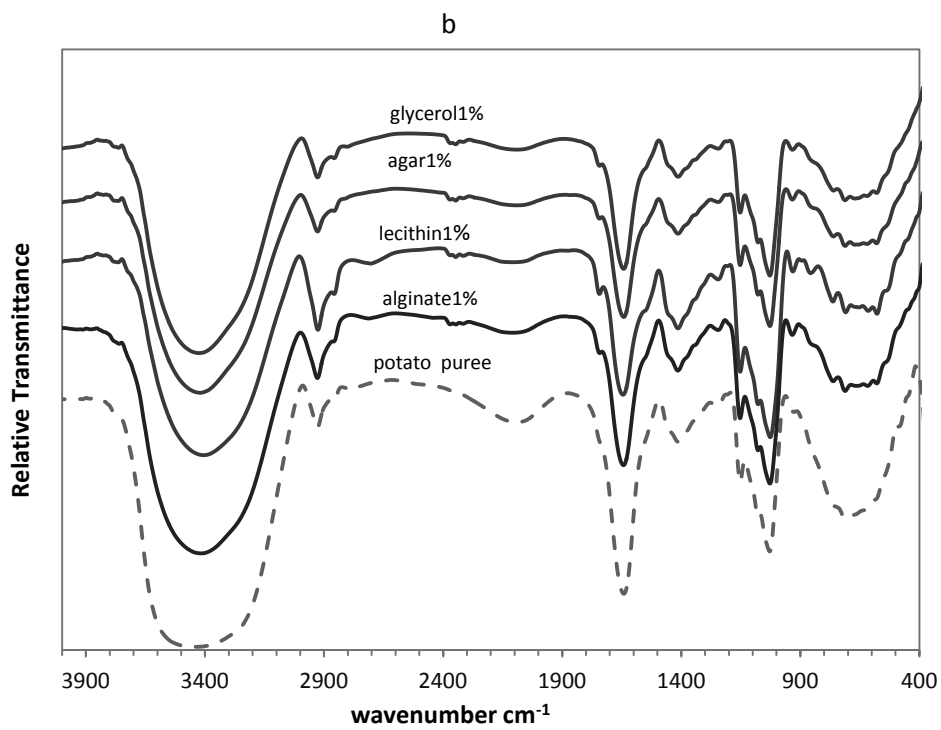
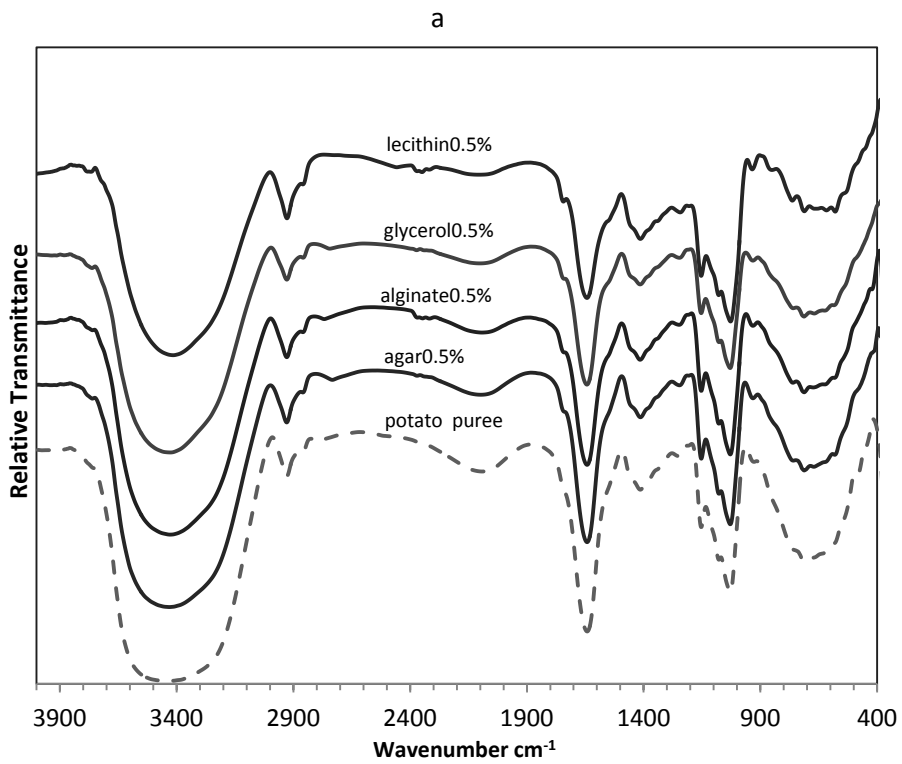


Figure 1. FTIR of raw potato, commercial potato powder and potato puree prepared by using commercial potato powder.

Figure 2
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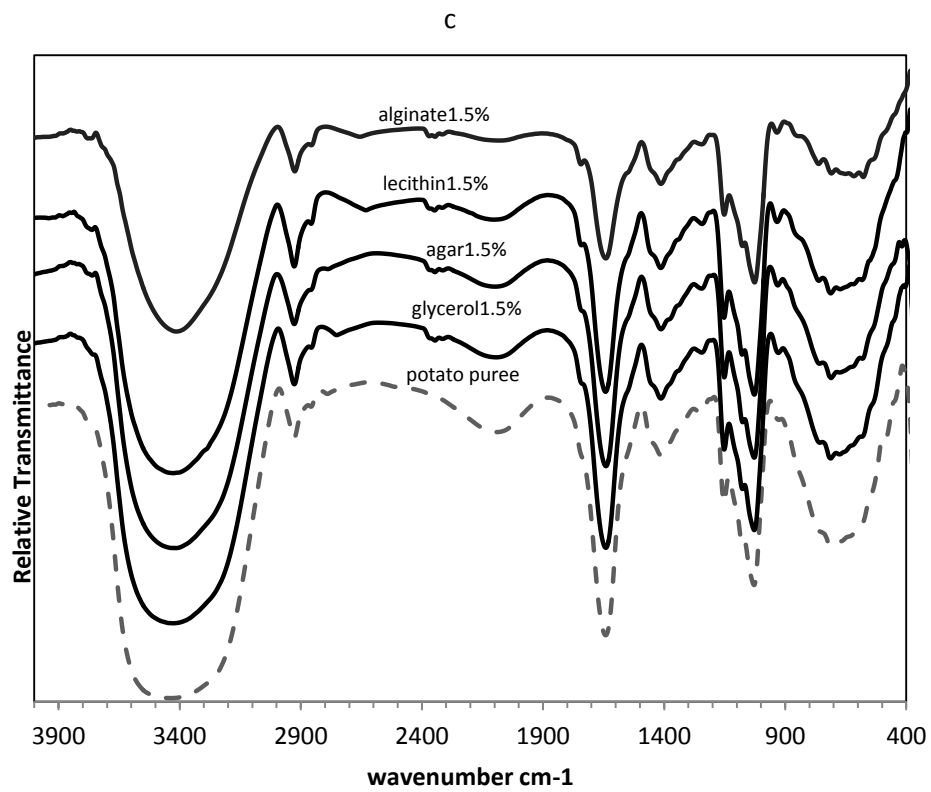
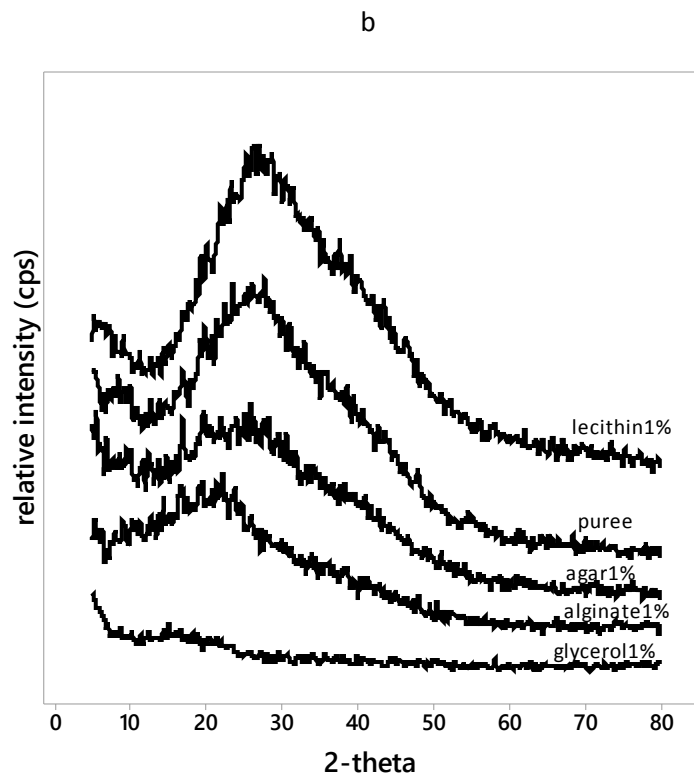
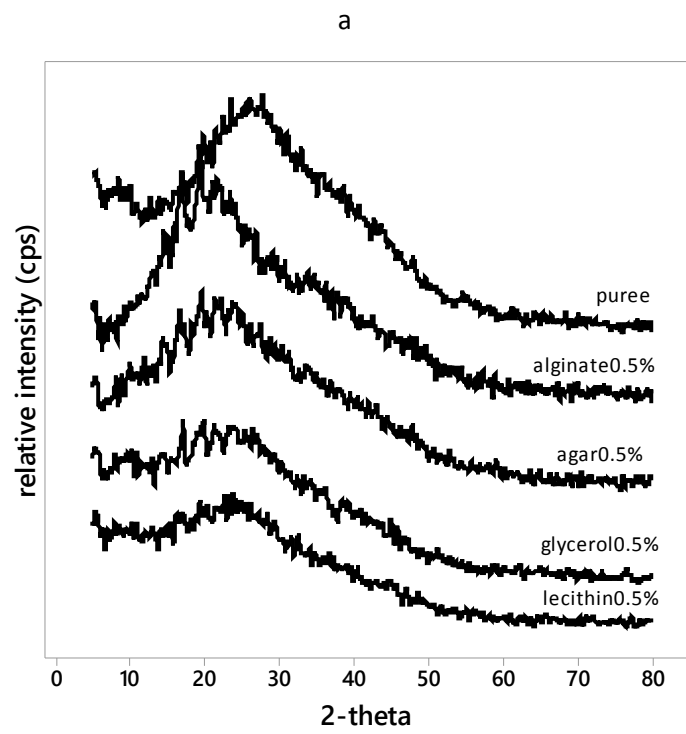


Figure 2. FTIR of potato pure and potato puree containing additives at different concentration: 0.5% a; 1% b and 1.5% c.

Figure 3
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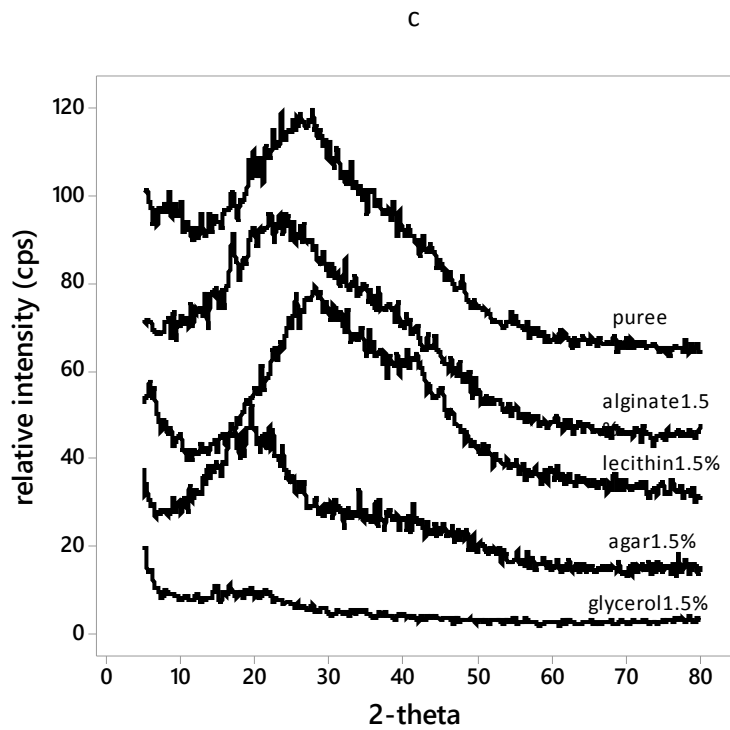


Figure 3. X-Ray diffraction patterns of potato puree and potato puree containing additives at different concentrations: 0.5% a; 1% b and 1.5% c.