

1 **A comparison of the sensory and rheological properties of different cellulosic** 2 **fibres for food**

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7 **Abstract**

8 The impact of different cellulosic microstructures formed by highly entangled fibre networks
9 were studied for food applications as dietary fibre. This paper reports the impact of
10 microstructure on the rheological and sensory behaviour of the aqueous suspensions of
11 particulate and fibrillated forms of softwood cellulosic fibres, and were compared with citrus
12 fibre. An aqueous suspension of cellulosic fibres shows stable viscoelastic gel-like behaviour
13 as a function of frequency. The particulate form of cellulosic fibres showed lowest shear
14 viscosity as compared to the entangled network system at comparable concentrations. To
15 provide further insight into the relationship between the structure of cellulosic fibre systems
16 and perception of salt taste in aqueous suspensions of softwood cellulosic fibres (fibrillated and
17 particulate form) and citrus fibres with matched shear viscosities were studied. A hypothesis
18 to explain why softwood cellulosic fibre (CTE) with entangled network structure prolongs the
19 taste perception is presented.

20 **1. Introduction**

21 Polysaccharides are known to be used as functional ingredients in a wide range of commercial
22 applications such as food, personal care and pharmaceutical products. In the food industry,
23 polysaccharides are used as thickening, gelling, emulsifying, stabilisation and coating agents
24 [1]. For these purposes, different natural polysaccharides such as starch, carrageenan, guar
25 gums and bacterial polysaccharides such as xanthan and bacterial cellulose are used. Typically,
26 a combination of two or more of these hydrocolloids is used to create a variety of

27 microstructures to formulate stable food applications with specific attributes like acceptable
28 mouthfeel and flavour perception. The processing conditions such as shearing, heating and
29 pumping of the polysaccharide mixtures result in microstructures with unique rheological and
30 sensory properties such as fat mimicking, and texture enhancement [2,3,4]. These
31 polysaccharides are typically categorised as dietary fibres in the food and pharmaceutical
32 industry. By definition, according to American Association of Cereal Chemists in 2000, dietary
33 fibres are referred to as the edible parts of plants or analogous carbohydrates that are resistant
34 to digestion and absorption in the human small intestine with complete or partial fermentation
35 in the large intestine [5]. Fibres are often classified as soluble dietary fibre and insoluble dietary
36 fibre [6]. These dietary fibres may consist of non-digestible carbohydrates, cellulose and lignin
37 that are an intrinsic part of a plant cell wall [7]. Depending on the source of fibres the amount
38 of soluble and insoluble components vary, for instance, the dietary fibre from fruits and
39 vegetables contains considerably higher proportion of soluble fibres, whereas cereal, peel of
40 fruits or other crops contain more insoluble components such as cellulose and hemicellulose
41 [8]. Dietary fibres play an important role in human health, as it was reported in past that high
42 dietary fibre diets are associated with the prevention, reduction and treatment of some diseases,
43 such as reducing cholesterol and maintain gastrointestinal health [9, 6].

44 The dietary fibre produced from citrus fruit such as CitriFi and Herbacel AQ+ are widely used
45 in various dairy products as a fat replacer, in low-fat mayonnaise, salad dressing and ice-
46 creams, providing fibre frameworks to improve water-holding capacity and therefore acting as
47 a thickening agent. Whereas in bakery products such as biscuits, croissants and muffins *etc.*
48 these fibres are used as fat and calorie reducing agents without compromising taste, texture and
49 cost [8, 10]. The rheological parameters such as flow behaviour and viscoelastic behaviour of
50 the different food applications or model systems can be correlated with the sensory texture
51 properties and stability of the products [11, 12]. Depending on the source, type and
52 concentration of fibres used in the product, different rheological and textural properties can be

53 achieved. For instance, the presence of xanthan gum improves the texture and physical shelf-
54 life of oil-in-water emulsions such as a salad dressing. The citrus fibre in combination with
55 another stabiliser such as xanthan or LBG improve the physical, chemical and sensory
56 properties of ice-cream samples [13, 14]. Similarly, a number of other cellulosic fibres are used
57 in the food industry such as MCC (microcrystalline cellulose), CMC (carboxymethyl cellulose)
58 and the other chemically derivatised celluloses such as methylcellulose.

59 Rheologically, a number of studies showed that an aqueous suspension of citrus fibres and
60 cellulosic fibres such as MCC or MFC (microfibrillar celluloses) shows gel-like behaviour
61 where the storage modulus (G') is higher than the loss modulus (G'') over a wide concentration
62 range. These moduli show little frequency dependence at all concentrations [15, 16, 17, 18,
63 19]. The higher elastic modulus might be due to long fibrils and fibrillar-aggregates and
64 entangled microfibrils, forming strong network structures. These aqueous suspensions of
65 different cellulosic fibres also exhibit shear thinning behaviour [16, 20]. Similar rheological
66 properties were observed by an aqueous suspension of dietary fibres extracted from tomato
67 peel/pomace and date [21, 22]. The objective of the current publication is to provide an insight
68 into the rheological properties of microfibrillar cellulosic fibre extracted from softwood spruce
69 and understand the fundamental differences between the different cellulosic fibre
70 microstructures and their functionality in food.

71 In recent years, an increase in demand for the low-salt food products was reported by the food
72 industry, due to continuous awareness from health professionals. Associations have been made
73 between a high sodium diet and an increased risk of certain health conditions such as
74 hypertension and cardiovascular disease [23, 24]. Hence, the World Health Organisation
75 (WHO) recommendations for a daily salt intake limit of 5g, recognising that many consumers
76 exceed this limit approx. $> 10\text{g}$ [26]. However, salts play many important roles in food products
77 not just as a tastant enhancing flavour, but also affecting physical properties, shelf-life and

78 finally prevention of fermentation (Lynch *et al.*, 2009). Different salt replacement work has
79 been presented in the past such as in bread; salt (NaCl) replaced with potassium or magnesium
80 salts resulted in unpalatable metallic, bitter and off-taste [27]. Rama (2013) showed that the
81 size of salt crystals influenced the rate of salt perception. It was reported that the larger salts
82 crystals dissolved relatively slowly as compared to small salt crystals, this prolongs the
83 duration of the taste perception. Ultimately, the smaller salt crystals meant less salt was
84 required to achieve a similar level of salty taste [28]. It is well established that as the viscosity
85 of the hydrocolloid thickened product increases, the flavour perception of the product decreases
86 especially when the concentration of hydrocolloid exceeds the critical overlap concentration
87 *i.e.* c^* [29, 30, 31]. This decrease in flavour perception is due to a reduction in the amount of
88 tastants reaching the sensing organs [32] due to an increase in viscosity of the system.
89 Depending on the type of hydrocolloid used in the product a noticeable impact on flavour and
90 taste perception is observed, for instance, the products thickened with starch showed good taste
91 and flavour perception as compared to product thickened with xanthan [33, 34].

92 The primary aim of this study then is focused on understanding the impact of highly entangled
93 networks of cellulosic fibre from various sources and their impact on rheological properties of
94 the suspension. It is hoped that this understanding will shed light on the potential application
95 of cellulosic fibres extracted from softwood (spruce) in food applications. A detailed study of
96 microstructure was performed by using light microscopy and correlated with water retention
97 capacity and rheological behaviour of the suspensions. The second objective of the work was
98 to test the impact of the highly entangled network of cellulosic fibres on overall taste (sensory)
99 perception from a basic food model system composed of cellulosic fibres, water and salt. A
100 detailed study of rheological behaviour and the sensory perception of the cellulosic fibres,
101 when correlated with light microscopy, as presented here, will enable important structural
102 features of these cellulosic materials to be identified which are of relevance to the food and
103 personal care industries alike. The hypothesis underpinning this research is that the highly

104 entangled network microstructure of cellulosic fibres are responsible for higher water retention
105 capacity which also reflects significantly on higher rheological properties and lowers the taste
106 (sensory) perception.

107 **2. Materials and methods**

108 *2.1. Materials*

109 For this study different food grade, cellulosic fibres: citrus fibres CF100 and CFAQ+ were
110 provided by Cybercolloids, Ltd (Ireland) and CTE (Flakes and Powder form, and are composed
111 on softwood spruce cellulose (CTE) and carboxymethyl cellulose (CMC)) was provided by
112 Borregaard AS (Norway). Reverse osmosis (RO) water was used for all sample preparation.
113 Sensory data was collected using FIZZ 2.0 software (Biosystems, Couternon, France).

114 *2.2. Sample preparation*

115 All cellulosic fibres were dispersed in RO-water by using a high shear Ultra-turrax
116 homogeniser at 18000rpm for 4 minutes at different concentrations (between 0.1% - 2.5%
117 w/w). All the samples were left to hydrate overnight on roller bed (60rpm speed) at ambient
118 temperature before analysis. The concentration of all the sample was checked by using OHAUS
119 MB25 moisture analyser (OHAUS, US). All samples were freshly prepared in two batches and
120 analyses were made in duplicate. For sensory analysis different cellulosic fibres (*i.e.* CTE
121 (flakes), CTE (Powder), CF100 and CFAQ+) were dispersed in 0.2% NaCl stock solutions at
122 different concentrations at comparable viscosities *i.e.* high (0.2Pas) and low (0.01Pas) at 50s⁻¹
123 shear rate (summarised in Table 1) and also at constant concentration (1.5% w/w). All samples
124 were mixed by using a high shear mixer (Silverson, UK) at 5000rpm for 5mins. All samples
125 were stored at 4°C overnight and stirred well before serving to panellists. For sensory analysis,
126 all ingredients are commercially available and commonly used in a variety of food products.
127 Prior to sensory evaluation, all panellists were informed of the ingredients and any possible
128 allergens highlighted in accordance with local Sensory Centre procedures.

129 **Table 1:** *Different concentrations (Concn %) of cellulosic fibres and corresponding shear*
 130 *viscosity (at 50s⁻¹) used for sensory analysis.*

Sample	High Viscosity		Low viscosity	
	Concn (%)	Shear Viscosity (Pas)	Concn (%)	Shear Viscosity (Pas)
CTE (F)	1	6.56	0.2	0.194
CTE (P)	1.5	5.59	0.5	0.0918
CFAQ+	1	5.35	0.8	0.0812
CF100	2	7.45	0.5	0.0918

131

132 *2.3. Rheological Analysis*

133 The rheological measurements were carried out on a stress-controlled Rheometer (Physica
 134 MCR 301, Anton Paar, Austria) with a serrated parallel plate (50mm diameter with a gap of
 135 1mm) at 20±1°C, controlled by a Peltier system. Small oscillation amplitude sweeps were
 136 generated by log ramping strain 0.01-100% at a constant frequency of 1Hz. Frequency sweeps
 137 were performed over the frequency range 0.1-15Hz at a constant strain of 0.2% which lay
 138 within the linear viscoelastic region. Rotational measurements were performed by increasing
 139 the shear rate from 0.01-1000 1/s log. Data presented is an average of four replicates.

140 *2.4. Sensory evaluation*

141 Panellists (n= 74, aged 20–40, mixed male and female volunteers) were recruited from the
 142 University of Nottingham staff and students. The four samples (CTE (flakes), CTE (Powder),
 143 CF100 and CFAQ+) were compared for saltiness using a round robin of paired comparison
 144 (PC) tests (BS EN ISO 5495:2007), such that each sample was evaluated against every other
 145 sample within the set of four, ensuring a total of 6 paired comparison tests. Three separate
 146 sessions were performed to examine the saltiness perception at a low viscosity (0.1Pas,
 147 Panellist: 74), high viscosity (6Pas, Panellist: 74) and at matched fibre concentration (1.5%
 148 w/w, Panellist: 60). The sample size was 10ml throughout and samples were served at room
 149 temperature (20±1°C). For each test the panellist had to take the whole sample in their mouth,

150 allow the sample to coat the roof of their mouth, hold in the mouth for a minimum of 5 seconds
151 before swallowing, and then cleanse their palate with unsalted crackers (99% Fat Free,
152 Rakusen's, Leeds, UK) and mineral water (Evian, France) before tasting the next sample.
153 Panellists were instructed to determine which of the 2 samples was highest in 'saltiness'. Rest
154 breaks were given between every 3 paired comparison tests. The test was used in forced-choice
155 mode, so panellists were required to give an answer even if the perceived difference was
156 negligible. Panellists were asked to provide additional comments regarding any other
157 differences between the samples. All tests were carried out at the University of Nottingham's
158 Sensory Science Centre, within individual sensory booths under controlled temperature and
159 humidity. Testing was performed under red light in order to minimise any small differences in
160 sample colour not relevant to the test. All the experiments were performed in compliance with
161 UK legislation (ISO standards), and in accordance with the institutional framework and
162 practices established by the University of Nottingham Ethics Committee. All participants
163 received written information about the study before giving their informed consent.

164 *2.5. Microscopic analysis*

165 Light microscopy of all aqueous suspensions of samples was performed by using Olympus
166 BX5 bright field light microscopy at 20X magnification, scale bar 200µms, all fibres were dyed
167 using Congo red dye (Sigma-Aldrich, UK).

168 *2.6. Water Retention Values (WRV):*

169 Approximately 0.1g (A) of powder was added to 100g water and mixed with an Ultra-turrax
170 for 4mins at 18000rpm. The mixture was placed in a centrifuge tube and allowed to rest for
171 2hrs followed by centrifugation (Beckman Centrifuge machine, Model: J2-21) for 30mins at
172 2141g. The top water layer was removed and the bottom layer weighed (B). This was done in
173 duplicate, and WRV was calculated by using Equation 1 (Eq.1).

174 Calculation: $WRV (\%) = (\text{Bottom layer (B)-starting material (A)})/\text{starting material (A)}$ Eq. 1

175 2.7. Data Analysis

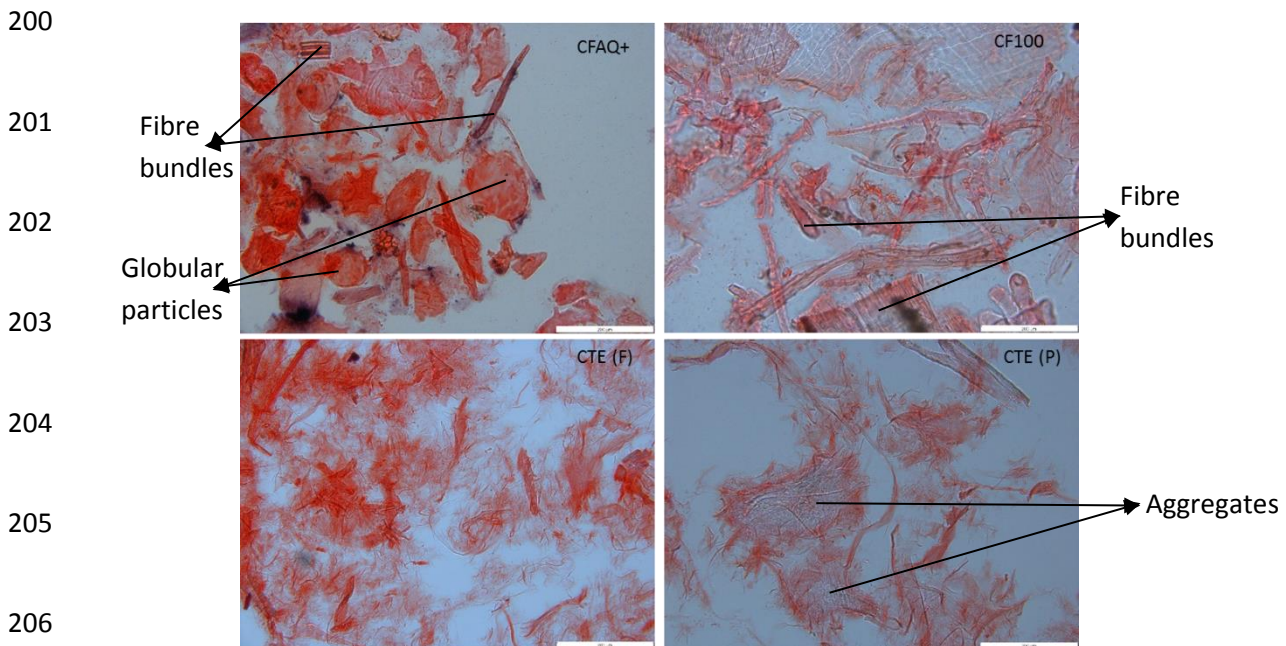
176 Sensory data were collected by using FIZZ 2.0 sensory software (Biosystems, Couternon,
177 France) and statistical analysis was performed by using Friedmans approach (significant level
178 $\alpha=0.05$). Rheology and WRV data were analysed by using ANOVA. The main purpose of the
179 ANOVA test is to identify and quantify the factors which are responsible for the variability of
180 the response.

181 3. Results and Discussion

182 3.1. Microstructure of cellulosic fibres:

183 Light microscopy images of different cellulosic dietary fibres at 1.5% w/w concentration are
184 presented in Figure 1. A noticeable difference in the microstructure was observed while
185 comparing CTE(F) or CTE(P) with the citrus fibres CF100 and CFAQ+. The aqueous
186 suspension of CTE(F) showed a dense entangled fibre network whereas larger aggregates and
187 fibre bundles were observed with CTE(P). CTE(P) samples were produced by further milling
188 process of CTE(F) product. During the milling process, the system exhibits slight moisture
189 loss, hence fibres form strong intermolecular interactions (common phenomena known for
190 cellulosic fibres upon drying or moisture loss with an increase in temperature), which explains
191 the noticeably higher amount of fibre aggregates upon hydration. The aqueous suspension of
192 citrus fibres *i.e.* CF100 and CFAQ+ showed multiple components (both soluble and insoluble)
193 in the system such as short fibre bundles of fibre, globular structures which are believed to be
194 pectin and other cell wall material (similar microstructures were observed by Córdoba *et al.*,
195 2010 with lemon fibres). Larger cellulosic fibre bundles and noticeably less interconnected
196 fibre-network were observed in the case of both CFAQ+ and CF100 (Figure 1). These highly
197 entangled fibre network microstructures are responsible for the noticeable difference in both

198 water retention value (also known as water retention capacity) and rheological properties of the
199 suspensions, discussed below.

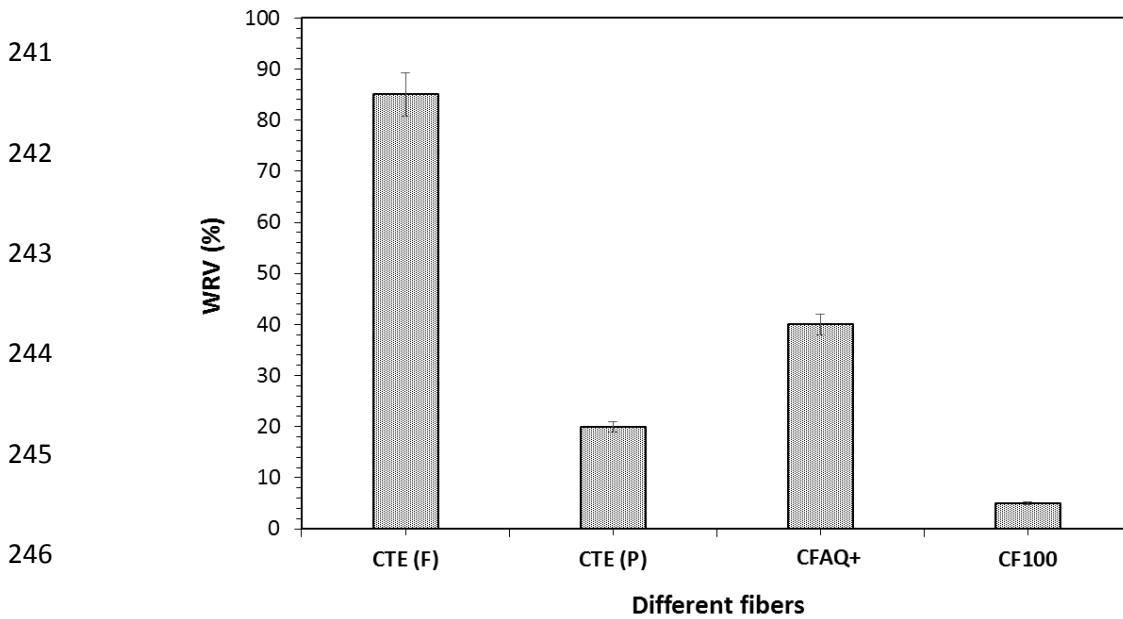


207 **Figure 1:** *Light microscopy images of 1.5% aqueous suspension of different cellulosic fibres*
208 *stained with Congo red dye, scale bar: 200µms.*

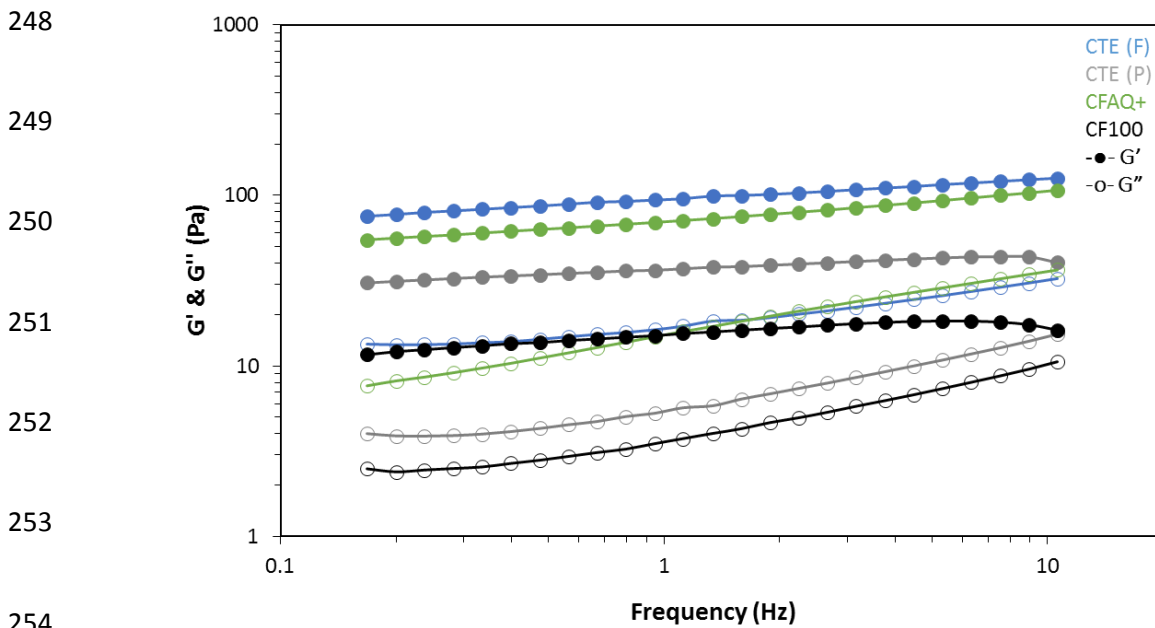
209 Water retention value (WRV) is an important property of dietary fibres from both a
210 physiological and technological point of view. It helps in understanding the behaviour of
211 dietary fibres in food applications or during gut transit. WRV of the different cellulosic fibres
212 are presented in Figure 2, a significant difference (p -value <0.05) in WRV was observed when
213 comparing the softwood cellulosic fibre (CTE(F) and CTE(P)) and citrus fibres (CF100 and
214 CFAQ+). This significant difference in the WRV can be explained by the different
215 microstructures, inherent formulation (soluble and insoluble components present in the system)
216 and different processing. It is well established that the processes such as drying, grinding,
217 heating or extrusion process modifies the physical properties of the fibre matrix and hydration
218 properties [35, 36]. Sangnark & Noomhorm (2003) and Elleuch (2011) reported that the
219 grinding can damage the regions of potential water retention capacity and, therefore, decrease
220 the capacity to hold water [37, 38]. This explains why lower amounts of water were retained

221 in the CTE(P) fibre-network (milled product) whereas higher amounts retained in CTE(F)
222 network structures. A slight loss of moisture during the process might have introduced different
223 intermolecular interactions, resulting in larger amount of aggregates (evident in Figure 1), these
224 aggregates are difficult to hydrate hence reducing the water retention capacity. Whereas lower
225 WRV of citrus fibres suspensions can be explained by larger fibre bundles, a noticeably less
226 interconnected fibre network and the presence of other soluble and insoluble components
227 present in the case of CFAQ+ and CF100 (Figure 2 and Figure 1; similar behaviour with other
228 citrus fibres was reported by Grigelmo-Miguel *et al.*, 1999 [39]). Interestingly, the WRV of
229 CFAQ+ was higher than CF100 this can be explained by two factors *i.e.* (1) inherent differences
230 in the soluble and insoluble content in the formulation, and (2) entangled network structure
231 formed during the processing of these fibres. The difference due to the formulation correlate
232 well with WRV reported with orange dietary fibres [39], lime peel [40], mango dietary fibre
233 [41], peach dietary fibre [42] and carrot dietary fibre [43]. Also, it is evident from the
234 microstructure of citrus fibres in Figure 1, that the CFAQ+ has slightly smaller fibre size and
235 is much more entangled than CF100, hence affecting the water retention capacity of the fibres.
236 It is well established that the hydration and water retention capacity of dietary fibres are very
237 important factors in the food industry as these factors can influence the ingredients
238 functionality, shelf life and product yield [44, 45]. The high WRV of CTE(F) suspension

239 suggested that the material could be used as a functional ingredient in food applications just
 240 like the industry established citrus fibres.



247 **Figure 2:** Water retention values (WRV %) of different cellulosic fibres.

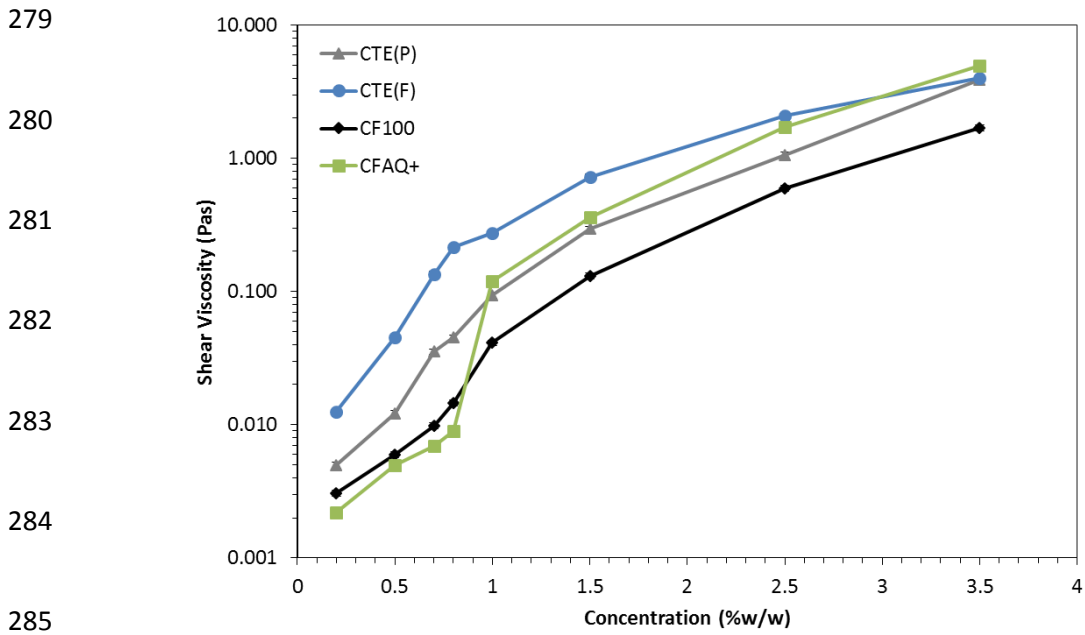


255 **Figure 3:** Dynamic mechanical spectra of 1.5% w/w aqueous suspension of CTE(F), CTE(P)
 256 and citrus fibres i.e. CFAQ+, CF100, where storage modulus (solid symbols) and loss modulus
 257 values (unfilled symbols) are represented as a function of frequency measured at $20 \pm 1^\circ\text{C}$.

258 **3.2. Rheological properties of cellulosic suspensions**

259 **3.2.1. Viscoelastic behaviour:**

260 Storage modulus (G') and loss modulus (G'') as a function of the frequency of an aqueous
261 suspension of CTE (F and P) and citrus fibres *i.e.* CFAQ+ and CF100 are presented in Figure
262 3. All suspensions showed viscoelastic gel-like behaviour, where storage modulus was higher
263 than loss modulus with little dependency on frequency. Similar behaviour was observed with
264 lemon fibres by Cordabo *et al.*, 2010 [17] and softwood cellulosic fibres by Tatsumi *et al.*,
265 2007 [19]. Slight dependency of G' & G'' on the frequency indicates that the network structure
266 formed by cellulosic fibres (independent of source) is in an active mode of forming
267 entanglements to form a stable network of fibres, producing a suspension with gel-like
268 properties. Chen (2013) suggested that high frequency increases the mobility of microfibers in
269 aqueous suspension, this increased mobility of the microfibers results in increases the
270 entanglement and formation of densely ordered network structure which reflects on viscoelastic
271 behaviour [46] . At a comparable concentration of 1.5% w/w, the elastic moduli of CTE(F) was
272 highest, where $CTE(F) > CFAQ+ > CTE(P) > CF100$, following the same trend for WRV (Figure
273 2), and visually explained when considering the highly entangled network of the CTE(F)
274 aqueous suspension (Figure 1). The aqueous suspension of CF100 showed the lowest moduli,
275 WRV values and have relatively large and discrete fibre particulates in the matrix, which
276 explains the weak viscoelastic behaviour of the suspension. Whereas, CTE(F) flakes show
277 higher moduli when compared to CTE(P) powder form, and can be explained by the retention
278 of a more fibrillated structure (Figure 1) resulting in higher water retention values (Figure 2).



286 **Figure 4:** Concentration dependence of shear viscosity (Pas) recorded at shear rate $50s^{-1}$ for
 287 four different cellulosic fibres, where (○) CTE(F), (Δ) CTE(P), (◇) CF100, and (□) CFAQ+.

288 **3.2.2. Concentration dependence of shear viscosities:**

289 Shear viscosity recorded at a shear rate of $50s^{-1}$ as a function of concentration is presented in
 290 Figure 4, and again shows the trend $CTE(F) > CFAQ+ > CTE(P) > CF100$, indicating that the
 291 shear viscosity is dependent on the source, processing and microstructure of cellulosic fibres.
 292 At the highest concentration studied (3.5% w/w) the CFAQ+ showed a higher viscosity than
 293 CTE(F), indicating that when the dispersions become highly packed the insoluble particles of
 294 CFAQ+ become dominant in the measured viscosity outcome, and the entangled nature of the
 295 CTE(F) is less effective at providing a measured viscosity. From a colloidal point of view, this
 296 then may be considered as an effect of ‘hard’ versus ‘soft’ and deformable particles. However,
 297 for some food applications such as ice-cream, mayonnaise, salad dressings *etc.*, a maximum
 298 concentration of 0.8% w/w is recommended for citrus fibres considering the sensory perception
 299 without any off-flavour, body and texture defects [13]. Considering the maximum
 300 concentration 0.8% w/w for certain application, CTE(F) showed higher shear viscosity as
 301 compared to other cellulosic fibres (Figure 4). These results indicate that to achieve specific

302 target viscosity (in the range of normal liquid-like foods) a lower concentration of CTE(F) is
303 required as compared to other fibres(Figure 4 and Table 1). Such results of being able to match
304 the viscosity of the different fibres in model systems can be considered for the purpose of
305 investigating whether the inherent properties of the materials themselves can have an impact
306 on sensory characteristics of texture and taste perception analysis.

307 *3.3. Sensory perception*

308 Figure 5 summarises the results from the sensory panel at the same concentration and matching
309 viscosities (low and high viscosity) of four cellulosic fibres. In figure 5a, no significant
310 differences (p-value > 0.05) was found in saltiness perception of the four product at the same
311 concentration (1.5%w/w). This can be attributed to the fact that at this concentration, where
312 differences in moduli and WRV were seen, all measured viscosities, at 50s^{-1} , were $>500\text{mPas}$.
313 This is significantly higher than the viscosity known to be important for decreasing the taste
314 perception in entangled polymeric systems [29, 30], above critical concentration (c^*), and
315 therefore at these higher viscosities, the effect of the fibre type is not apparent. Figuerola
316 (2005) showed that texture was strongly dependent on the particle size in the case of citrus
317 fibres [47]. Due to a noticeable difference in the microstructure of all four fibres at the same
318 concentration, as expected, panellists reported CTE(F) suspensions were much thicker as
319 compared to other cellulosic fibres suspensions (results not shown).

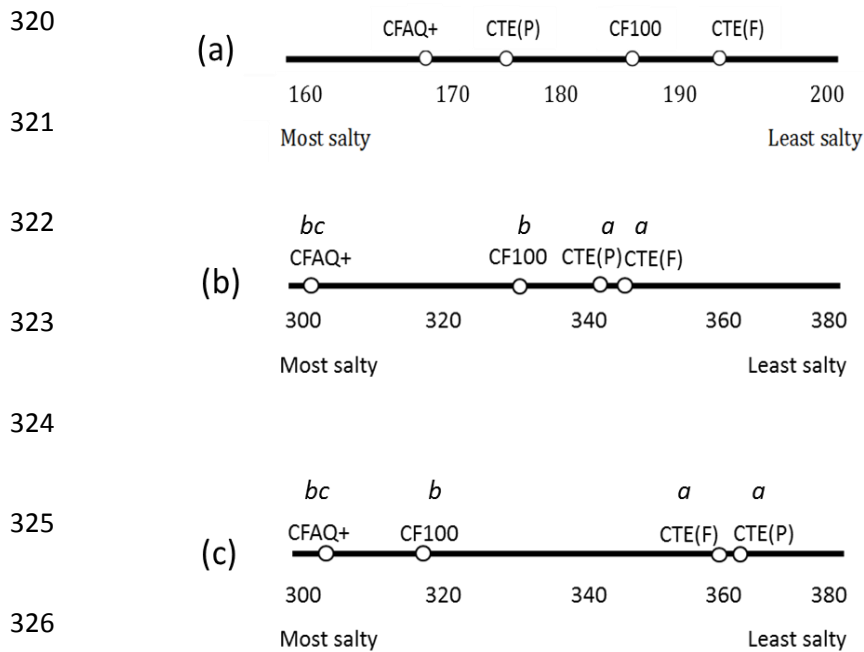


Figure 5: Rank sum scores of each sample (CFAQ+, CF100 and CTE(F) and CTE(P)) for saltiness perception, where a decreasing numerical value corresponds to an increase in the attribute. (a) At constant concentration i.e. 1.5% w/w, (b) At matched high viscosity (0.2Pas), and (c) At matched low viscosity (0.01Pas) salt suspensions [a, b, c represents the statistical significance, where the same letter indicates no significant difference, different letters indicate a significant difference with p -value < 0.05 . Note: *bc indicates that no significant difference between CF100 and CFAQ+, but there is a significant difference (p -value < 0.001) between CFAQ+ and CTE fibres.

It was evident from the rheological analysis in Figure 4, that an aqueous suspension of CTE(F) shows higher shear viscosities and this difference in shear viscosity explains the difference in thickness perception noted by the panellists during sensory analysis of 1.5% w/w suspension of different fibres. In the comments section, most of the panellists found a strong off-taste (described as ‘citrus/lemon taste’) with CF100 and little off-taste with CFAQ+ suspensions. Whereas the absence of such off-taste was reported by the panellists (evident with no comments from the panels and even some panel mentioned no-off-taste when comparing with CF100 and CFAQ+) in the case of CTE(F) and CTE(P) suspensions.

343 In order to remove the impact of the difference in viscosities at the same concentration,
344 different suspensions were formulated with matched viscosities (low and high) but different
345 fibre concentrations. Using the paired comparison test, it was found that at high viscosity, a
346 significant reduction (p -value < 0.05) in saltiness perception was observed with CTE(F) and
347 CTE(P) suspensions as compared to CF100 and CFAQ+ (Figure 5b). No significant difference
348 in terms of saltiness perception was observed between CTE(F) and CTE(P) as p -value > 0.05 .
349 Similar taste perceptions were observed with the suspensions at lower viscosities of different
350 cellulosic fibres (Figure 5c). The granular suspension of CF100 and CFAQ+ is believed to be
351 the cause of their higher saltiness perception, in line with similar behaviour found in particulate
352 suspensions such as starch and xanthan, in that if the granular structure was maintained during
353 processing, the system does not reduce the taste perception at high concentration [33, 34, 48].

354 A significant difference in saltiness perception and thickness between CTE products and citrus
355 fibres (CFAQ+ and CF100) can be explained by the dense network structure afforded by the
356 fibrillated cellulose – now acting more like a polymeric solution, resulting in reduced taste
357 perception. While the differences in taste perception were significant between the CTE samples
358 and the citrus samples, for both high and low viscosity, the positioning on the rank sum scoring
359 for the higher viscosity systems was narrower. This then also indicates that all systems at the
360 higher viscosities tend to behave as a concentrated dispersion, exemplified at the higher
361 viscosities seen for the 1.5%w/w samples, where there was no difference seen between
362 samples. In summary, it was evident from the sensory analysis, that the CTE samples with
363 highly entangled network structure lowers the taste perception as compared to particulate
364 suspensions such as CF100 and CFAQ+.

365 **4. Conclusions**

366 The influence of a highly entangled fibre network of cellulosic fibres on the rheological
367 properties of a suspension is consistent with water retention values of these fibres and a key

368 factor which may responsible for lower taste perception. Rheological measurements show that
369 all cellulosic suspensions showed viscoelastic gel-like behaviour, due to highly dense fibrillar
370 and particulate networks affording high water retention capacity. The difference in
371 microstructures and inherent composition of different cellulosic fibres are responsible for
372 difference in sensory (tastant) perception. Aqueous salt suspension at matched viscosities of
373 softwood cellulosic fibre samples showed lower saltiness perception as compared to citrus
374 fibres. It appears that the particulate structure releases the tastant more effectively and faster as
375 compared to highly fibrillated and networked systems. The results presented in this paper
376 clearly highlights that the choice of dietary fibre needs to be made carefully when considering
377 the application in food products. A highly entangled network microstructure of cellulosic
378 fibres, responsible for higher water retention capacity greater rheological properties may be
379 beneficial for certain structural and nutritional aspects of food products, but if taste release is
380 of importance, for increase sensory perception, then a fibrillated fibre would not be preferred
381 over a more particulate material.

382 **Conflict of Interest**

383 There are no conflicts of interest to declare.

384 **Acknowledgement**

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