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1 Selecting tomato for their ability to react and conserve their quality during
2 the process

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21 **Abstract**

22 **The quality of tomato based products greatly depends on their color and**
23 **viscosity, which are influenced by the fruit capacity of modifying their properties**
24 **according to the processing route. Loss of viscosity due to intrinsic pectin modifying**
25 **enzymes (also called 'fruit reactivity') is known and used to produce either hot break**
26 **(HB) purees, more viscous, or cold break (CB) ones, less viscous. Color reactivity, even**
27 **if less documented, also exists as HB/CB purees differ.**

28 **This fruit reactivity, although essential for quality purpose, remains almost**
29 **neglected from breeders. In order to verify if reactivity could be considered as a**
30 **heritable trait, we measured it through a "quick and dirty" laboratory scaled process**
31 **and a systematic measurement of the loss of texture and color according to HB or CB**
32 **process.**

33 **The results indicated that fruits can be classified according to their capacity of**
34 **being impacted by the process. For viscosity, some genotypes exhibited a strong**
35 **capacity for producing highly viscous purees but also exhibited a strong fruit**
36 **reactivity, indicating that their advantage may be quickly lost during the process if**
37 **the first break step is not efficient enough, or in case of cold break processing. On**
38 **other hand, some genotypes exhibited a very low reactivity to process. Reactivity was**
39 **also greatly reduced by a low irrigation level. And finally, a parallel processing at**
40 **laboratory or pilot scale indicated that the behavior of a 10-fruits sample in**
41 **microwaves was correlated to the quality observed in traditional scrapped surface**
42 **tubular eating system. The color of purees was also influenced by the fruit reactivity,**
43 **but the enzymatic basis for the color change seemed disconnected from the one**
44 **controlling viscosity.**

45 **Those results open the door for a more efficient screening of tomato varieties**
46 **based not only on the fruit composition, but also on their ability to react to the**
47 **process.**

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49 **Keywords:** Fruit quality, viscosity, color, tomatoes, processed products

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1. INTRODUCTION

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The quality of tomato products depend on their colour and their consistency, traditionally evaluated through Bostwick measurement. Consistency results from the biochemical as well as the structural properties of purees. The dry matter content is known for long as a major parameter related to consistency. Product concentration performed in industry through water evaporation result indeed in more viscous product. This evaporation is traditionally followed by the measurement of the refraction index (RI) (generally expressed in 'Brix' degree). Therefore, by extension, the 'Brix' value became a reference measurement to measure the fresh tomato quality, in order to predict the processed product quality.

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However, 'Brix' is a weak marker of puree quality. Indeed, the consistency of fruit purees is influenced by many other factors than soluble solid content. First of all, the dry matter content (DMC) is also constituted of 'structural' solid, (mainly fruit cell-wall material), which may represent up to 10% of the DMC, and which is not evaluated by IR (Ścibisz et al., 2011). It contains polysaccharides like pectin, highly influent on puree viscosity. As a result, in a large range of varieties, RI and DMC are not fully correlated (Arbex de Castro Vilas Boas et al., 2017). Moreover, many other parameters influence the apparent viscosity. Volume, shape and sizes of particles as well as the viscosity of the serum has been described as influent for the viscosity of apple and tomato purees (Espinosa-Muñoz et al., 2013). Finally, the processing route, depending if time/temperature parameters allow for the activity of fruit pectinolytic enzymes (like in cold break processing route), highly modulate the viscosity (Anthon et al., 2002; Barrett et al., 1998). Fruit enzymatic reactivity, as depending on their enzyme content, may also constitute a valuable genetic parameter to qualify varieties for their ability to produce high quality product.

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The objective of this work was to evaluate, on a large range of samples representative of the French tomato, the variability of quality parameters such as viscosity, colour and dry matter content. We also systematically apply a laboratory scale hot break (HB) and cold break (CB) processing, to evaluate the HB/CB difference of viscosity (Δ). As being due to pectinolytic enzyme activity, this Δ was considered as a marker of the intrinsic reactivity of the fruit. Its variability among samples and their correlation to quality parameters was evaluated.

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2. MATERIAL AND METHODS

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2.1. Plant material

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In 2015, tomatoes were collected from experimental trials performed by the French professional organisation of industry tomato (SONITO). A large variability of tomato fruits was obtained by collecting fruits of different varieties, from different areas of production (South-East and South-West of France) and harvested as full ripe fruits (according to commercial standard). 88 samples, corresponding to 39 genotypes were collected.

92

For each sample, 15 tomatoes were cut into pieces of 2 to 4 cm side, and separated as two identical samples prior to processing.

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In 2016, 8 batches of 250kg of tomatoes corresponding to two varieties (H1311 and Terradou) were grown in an experimental field including two irrigation regimes (Arbex de Castro Vilas Boas et al., 2017).

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2.2. 'lab' scaled processing:

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Each sample collected in 2015 were processed alternatively by hot break (HB) or cold break (CB) standard processing (Page et al., 2012). Quickly described: HB treatment consist

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103 in first heating the fruits (microwave oven) and then grinding them whereas, in CB
104 treatment, tomatoes were first ground, macerated at room temperature for 30 seconds
105 (allowing for intrinsic enzyme reaction) and then heated as for HB. The two processing
106 routes used the same heating and grinding energy, but the order of operation units changed.
107 After cooking, purees were stored into 400 ml glass jars, pasteurized (100°C, 15 min) and
108 stored at 4 °C until analyses. HB/CB standard processing induce a difference of viscosity due
109 to intrinsic enzymatic activities of fruits, and was, therefore considered as a proper genetic
110 trait, so called 'reactivity of the fruit' in this study.

111

112 **2.3. Pilot plant processing:**

113 Each of the 8 batches collected in 2016 were HB/CB processed in a pilot: For
114 HB, break temperature was fixed at 95°C, and then stabilization was for 5 min at 95°C by a
115 scraped-surface heat exchanger. For CB, tomatoes were crushed in the same hammer mill as
116 for HB, but macerated for 10 min at a break temperature of 40°C in an intermediate tank,
117 and then stabilized for 5 min at 95°C. Then both were refined through a 0.8 mm sieve,
118 concentrated until reaching an IR around 7 degree Brix, and product was canned into ¼
119 liter cans. The same tomatoes were also processed in the 'lab-scaled' methods in order to
120 compare their qualities.

121

122 **2.4 Quality traits analyses**

123 Soluble solids content (SSC) was determined with a digital refractometer (PR-101
124 ATAGO, Norfolk, VA) and expressed in °Brix at 20°C. The dry matter was measured by
125 drying 3g of samples in air oven (70°C, 96 h). Viscosity was measured at 20°C in a MCR-301
126 controlled stress rheometer (Anton Paar, Germany) : a steady state measurements were
127 performed with a double ribbon impeller (with an inner radius of 11 mm, a pitch of 45 mm,
128 a length of 45 mm) as described in (Espinosa-Muñoz et al., 2013). The color was measured
129 with a Minolta CR.400 calibrated with a standard background, and result express as the hue
130 angle, ie arc-tangent of the ratio a/b, from the L*, a, b colour values.

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132 **3. RESULTS AND DISCUSSION**

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134 **3.1 Validation of the laboratory scaled method**

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136 As a prerequisite for our studies, we verified that the laboratory scaled method used
137 for the evaluation of a standard enzymatic reactivity of fruits, (consisting in measuring a
138 systematic effect of HB/CB process) was in accordance with what is obtained in industry
139 type methods concerning the reduction of viscosity by a CB processing route as compare to
140 HB route. HB pilot purees exhibited a viscosity varying from 3 to 13 Boswick unit (Bw),
141 while CB purees ranged from 6 to 17 Bw. Purees from H1311 being clearly more viscous
142 than purees from Terradou, but Terradou exhibiting the highest delta of viscosity (HB vs
143 CB) (data not shown). Comparatively, laboratory purees, which did not receive any
144 concentration, ranged from 8 to 22 Bw. However, the two set of data were clearly correlated
145 (p-value< 0,001), indicating that the 'lab-scaled' methods seems an appropriate method not
146 only to classify HB purees according to their potential of producing viscous product, but also
147 to classify tomatoes for their capacity of losing their viscosity when processed in a cold
148 break route. In other words, this method seems appropriate to evaluate the intrinsic
149 enzymatic reactivity to process of tomatoes.

150

151 **3.2 Variability of puree quality of the French tomato production**

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153 Tomatoes from 88 samples (representing 39 genotypes) were collected all along the
154 area of production in France. They were systematically HB and CB processed by laboratory
155 scaled method, and classified for their quality (table 1). Their dry matter content varied
156 from 4.6 to 9.4, leading to a large range of viscosity for purees. HB viscosity varied from 0.8
157 to 5.3 Pa.s. In HB purees, no enzymatic maceration occurred, and therefore, HB viscosity can
158 be considered as the maximum potential of tomatoes to produce viscosity when they are
159 processed into purees. Comparatively, CB viscosity was lower, however, the HB/CB delta of
160 viscosity did not vary in parallel, as it ranged from 0.3 to 2.9, indicating that the enzymatic
161 potential for modifying viscosity differed from one sample to the other. Colours exhibited
162 also a large variability with hues varying from 0.65 to 1.07. The difference was mainly due to
163 the presence of high-pigmented tomatoes like Uno Rosso or H1311. In generally HB/CB
164 purees exhibited a visible difference of colour, as confirmed by the measurements (table 1).
165 HB purees were more 'orange' than CB. However, the differences were not systematically
166 the same for all samples.

167 **3.3 Variability of the reactivity to tomato processing**

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170 The correlations between data within the set of quality parameters measured for the
171 88 samples confirmed that viscosity cannot be only explained by the dry matter content of
172 tomatoes. DMC exhibited a low correlation with HB viscosity as well as with CB viscosity.
173 This result was already observed with tomato harvested in one area but varying for their
174 irrigation (Arbex de Castro Vilas Boas et al., 2017). But the most interesting findings of this
175 set of data came for the correlation between the delta of viscosity and either HB or CB
176 viscosity. Indeed, if delta was clearly correlated to HB viscosity, the correlation drop to a low
177 level with CB viscosity. This result indicated, not only that genotypes varied for their
178 capacity of losing viscosity but also that this reactivity is not related to the intrinsic potential
179 of viscosity as measured with HB viscosity. When enzymatic reaction occurred as it happen
180 with CB, the correlation was weaker. Despite this difference of reactivity, correlation
181 between CB and HB viscosity remained high, as genotypes producing a low HB viscosity
182 remain low when CB processed. However, points were more dispersed for high HB viscosity.
183 Some samples exhibiting an equivalent high HB viscosity either remained high or dropped
184 to a low value. This result clearly indicated that tomatoes do not exhibit an equivalent
185 reactivity to the process. We do not obtain such a clear result with the differences of colour
186 between HB and CB. It is not surprising, because, the differences of colour may result from
187 very complex physical reasons, which are not as straightforward as the relation of
188 pectinolytic enzymes with the digestion of pectin within cell-wall, which, in turn, as been
189 already described as a major factor for the loss of puree viscosity (Sánchez et al., 2002).

190 **CONCLUSIONS**

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192 One major finding of our study is that tomatoes exhibit a variable reactivity to the
193 process depending of their variety and their area of production. This reactivity, depending
194 of the intrinsic enzymatic content of fruits, is, to a certain limit, independent of the potential
195 properties of the varieties to produce high viscous product. Those last are indeed more
196 dependent of the structure of fruit tissues, and their capacity to resist to processing steps.
197 However, our experimental design did not allow for quantifying the heritability of the
198 reactivity, and this remains a perspective to this work. And additionally we indicate that a
199 'quick and dirty' laboratory scaled processing using microwave seemed appropriate for
200 classifying tomatoes according to their intrinsic potential to produce high/low viscus
201 product (HB viscosity) and also their potential reactivity to the process (Δ). However,
202 the validation of the methods in an industrial context need to be achieved.

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204

205 **Literature cited**

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229 Table:

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235 **Table 1. Variability of quality parameters of purees obtained from tomatoes from two**
236 **areas of production in France in 2015, and processed by laboratory scaled method**

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	DMC <i>(%)</i>	HB Viscosity	CB Viscosity <i>(Pa.s)</i>	Reactivity	HB Hue	CB Hue <i>(L*.a.b units)</i>
Min	4,6	0.8	0.1	0.3	0.65	0.78
Median	6,7	2.0	0.8	1.3	0.88	0.94
Max	9,4	5.3	2.6	2.9	1.07	1.04

241 Figures:
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Viscosity (laboratory)

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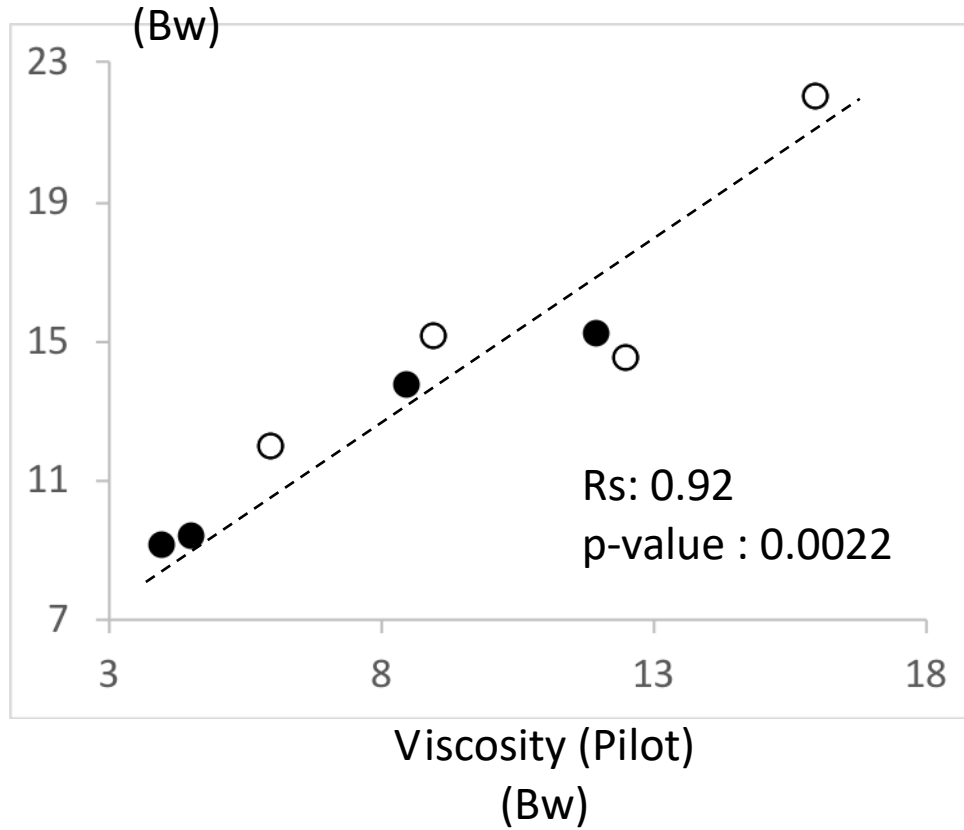
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Figure 1. Correlation between viscosities of purees obtained either laboratory or pilot

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scaled methods. Open circles are hot break processed purees, and black circles are cold break. Rs is the

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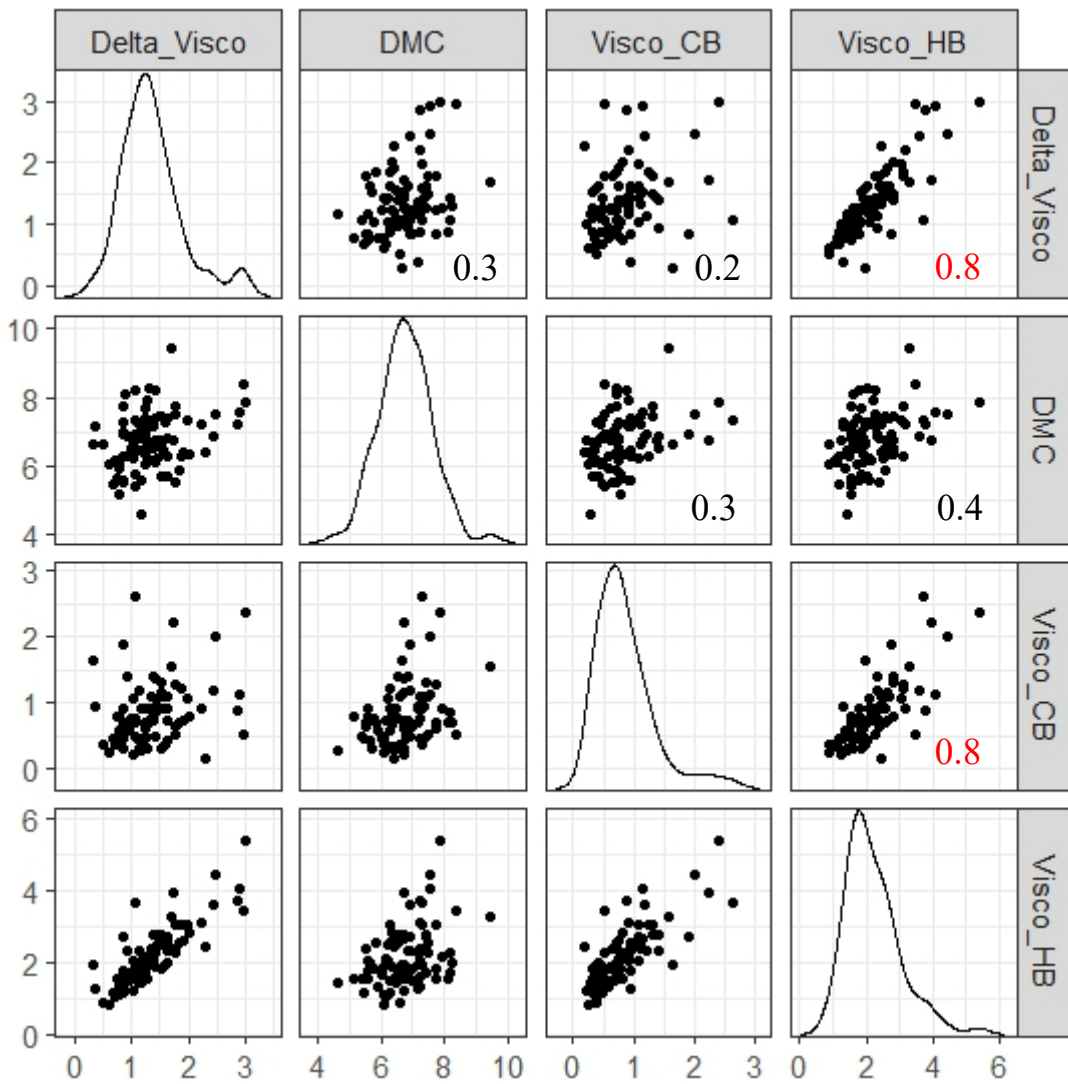
Spearman correlation coefficient, and p-Value is the associates probability of correlation (Spearman rank test

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correlation)

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Figure 2. Scatter plot matrix of dry matter content (DMC), Viscosity (hot break: HB and cold break CB), and the difference of viscosity between HB and CB purees (delta_visco). Pearson correlation coefficient are indicated for each pair of data, and only highly correlated (according to t-test, p-values <0.0001) are indicated in red