

# Cooking and Nutritional Characteristics of Malted Chickpeas

Alessio Cimini\*, Alessandro Poliziani, Lorenzo Morgante, Mauro Moresi

Department for Innovation in the Biological, Agrofood and Forestry Systems, University of Tuscia, Viterbo, Italy  
[alessandro.poliziani@unitus.it](mailto:alessandro.poliziani@unitus.it)

The consumption of chickpeas is disadvantaged by their long cooking times and thus great cooking energy needs, as well as undesirable tastes and smells and the presence of some anti-nutritional factors. This work was aimed at measuring the cooking and nutritional characteristics of a typical chickpea variety (the straight furrow chickpea, SDC) cultivated in the Latium Region of Italy, as such, decorticated or after malting. A three-stage (steeping, germination and kilning) process allowed their original contents of  $\alpha$ -galactosides and phytate to be reduced by about 57% and 31%, respectively. Once decorticated, malted SDCs were directly cooked in boiling water for about 45 min, while the 16-h presoaked raw counterpart needed a 30-min longer cooking process. Dehulled malted SDCs can thus assist the general consumer with shorter preparation times and more healthy and sustainable eating habits.

## 1. Introduction

The chickpea (*Cicer arietinum*) is an annual-cycle herbaceous plant belonging to the *Leguminosae* family which is largely subdivided into two groups, such as black chickpea or Desi, widespread throughout the Asian continent, and white chickpea or Kabuli from which the various varieties grown in Italy derive (Asif et al., 2013; Rawal et al., 2019). This work accounted for a white variety cultivated since Etruscan times named *Solco Dritto* (straight furrow) chickpea (SDC) from a rural tradition involving a furrow tracing in the plain beneath the town of Valentano (Italy) on the 14th of August of every year. Such a tracing straightness is regarded as a harbinger of an excellent harvest. SDC is nowadays farmed in a limited area (*Alta Tuscia*) of Central Italy in hilly volcanic soils, rich in potassium and poor in calcium, at a height between 300 and 400 m above sea level and mild climate, this giving such chickpeas superior organoleptic characteristics.

Like all other pulses, chickpeas must be cooked prior to consumption. The longer the cooking time the greater the cooking energy consumption will be. Since this is a deterrent for chickpea consumption, several research programs are attempting to breed quicker cooking chickpea varieties. Several methods have been so far tested to evaluate their cooking time. Unfortunately, no recognized standard method is available yet (Wood, 2017). For instance, the percentage of seeds penetrated by the 25 plungers of an automated Mattson cooker may vary from 50% to 100%, this obviously involving quite different cooking times. Wang and Daun (2005) assumed that the nominal cooking time for several pulses coincided with the time required for penetrating 80% of 25 seeds, pre-soaked in distilled water at room temperature ( $22 \pm 2$  °C) for 24 h and then placed into a 2-L metal beaker containing 1.2 L of boiling water. On the contrary, the American Association of Cereal Chemists (AACC) standard method 56-36.01 determines the firmness of a 40-g sample (pre-soaked in 160 mL of distilled water at room temperature for 24 h and then cooked in a 2-L metal beaker containing 1.0 L of boiling water for different times) by means of a compression test through a mini-Kramer shear cell (Wang et al., 2012). In this way, it is possible to assess how the pulse firmness varies with cooking time and thus determine its optimal value. Even if this measurement refers to a larger number of seeds and is in principle more reliable, it is troublesome for the difficult and time-consuming cleaning of the Kramer shear cell (Wood, 2017).

Not only long cooking times, but also other disadvantages, such as undesirable tastes and smells and the presence of anti-nutritional factors (i.e., phytic acid, tannic acid, polyphenols, and flatulence-causing  $\alpha$ -galactosides, like stachyose and raffinose) disfavor the consumption of chickpeas (de Almeida Costa et al., 2006). A malting process was previously used to reduce the content of such anti-nutrients and improve the taste acceptability and healthiness of chickpeas (Cimini et al., 2021) and lentils (Cimini et al., 2023).

The main aim of this work was to compare the chemico-physical characteristics of SDCs as such, decorticated or malted, as well as to determine their firmness against cooking time by means of a modified version of the above AACC method to check for the superior characteristics of malted chickpeas from the nutritional, convenience and sustainability points of view.

## 2. Materials and methods

The SDCs used in this work were produced and supplied by *Il Cerqueto* Srl (Acquapendente, Viterbo, Italy). Such yellow-beige skinned chickpea seeds were either soaked, dried and decorticated, or submitted to the malting process. Both procedures were schematically sketched in Figure 1. The malting process was carried out in the bench-top plant described by Cimini et al. (2021) and shown in Figure 2. All seeds before and after the malting process were characterized via the following physical tests: seed weight and volume, mean radius ( $R_s$ ), density, hydration capacity (HC), and swelling capacity (SC), as previously described (Cimini et al., 2021).

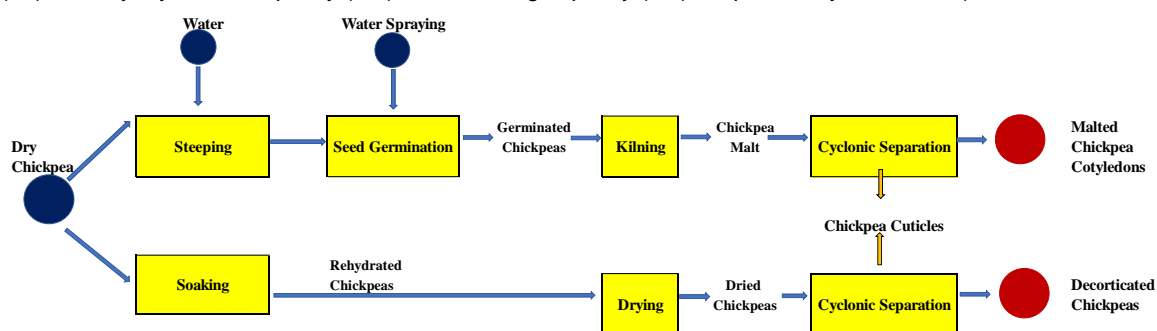


Figure 1: Block diagram of the production processes used to malt and de-husk SDC cotyledons.



Figure 2: Pictures of the bench-top plant used in this work: (a) insulated chamber and (b) perforated baskets.

The first phase of the malting process (*steeping*) was carried out at 25 °C for 5 h. Thus, the moisture content of seeds increased from 12 to about 49% (w/w). Thereafter, the steeping water was discharged and the seeds were let germinate for as long as 72 h. The degradation of their main antinutrients (i.e., phytic acid and  $\alpha$ -galactosides) was determined using the Phytic Acid and Raffinose/Sucrose/D-Glucose Assay Kits (Megazyme Ltd, Bray, Ireland), respectively. Germinated chickpeas were then dehydrated from a moisture content of  $48 \pm 2\%$  on a wet basis to  $10 \pm 2\%$  (w/w) at 45 °C for 4 h and then at 75 °C for 4 h using the Nobel Pro 6 ventilated dryer (Vita 5, Gronsveld, The Netherlands), thus obtaining the SDC malt. A cyclone separator was then used to split up the cuticle fragments from the cotyledons, this fraction representing  $85 \pm 2\%$  of the input SDC malt. The color of all the SDC seeds was determined in the CIELab color space using a portable color-measuring instrument mod. D25-PC2 (Hunterlab, Restow, Virginia, USA) with a diffuse (0/45°) illuminating viewing geometry, while their moisture content was determined as the seeds were roughly divided into parts and dried at 110 °C for ~20 min using a Kern DAB 100-3 thermostatic scale (Kern&Sohn GmbH, Balingen, Germany). Total starch and resistant starch fractions in seeds were determined using the corresponding kits by Megazyme Ltd (Bray, Ireland). Raw protein fraction was assessed by means of the method 992.23 (AOAC, 1998) with a nitrogen conversion factor of 6.25.

About 750 g of SDC seeds (as such) were weighted and transferred into a container. Then, tap water at 20 °C was added to set the soaking water-to-seed ratio at 4 g/g. The seeds were soaked at 20 °C for 16 h. Once the

soaking water had been drained, the moistened seeds were transferred into a stainless-steel pot containing 3 kg of boiling water and let cooking with the lid closed at 98 °C for 20-90 min using a 2-kW induction-plate hob (INDU, Melchioni Spa, Milan, Italy). Decorticated SDC cotyledons, as well as malted SDCs, were cooked without presoaking at 98 °C for 20-57 min with the pot initially filled with tap water at room temperature. The hob knob was set at the nominal power of 2 kW till the water started boiling, then it was shifted to 0.4 kW till the end of seed cooking. The electric energy supplied by the induction hob ( $E_s$ ) was monitored using a digital power meter type MP600 (RCE Srl, Salerno, Italy). The cooked chickpeas were recovered from the cooking water using a colander, cooled by running tap water for 90 s, and drained. A given quantity ( $70.0 \pm 0.5$  g) of them was loaded into an Ottawa Texture Measuring System (Techlab Systems, Itasca, IL, USA), this being a square test cell with solid walls and a perforated base, to submit any sample to a combined compression and extrusion test. The resulting Texture Profile Analysis (TPA) graph is like that obtained with the Kramer shear cell. A 4 cm x 4 cm probe was attached to the compression plate of a Universal Testing Machine UTM mod. 3342 (Instron Int. Ltd., High Wycombe, UK), equipped with a 1000 N load cell, to assess the compression force required to squeeze the sample. By setting its probe speed at 1 mm/s, the compression plate was lowered to adjust initially the height of each cooked sample to 20 mm and keep uniform the orientation of the seeds on the probe itself. Then, the latter was raised to its starting position. After a short relaxation time of 5 s, each specimen was submitted to two subsequent 25% compression cycles to imitate the action of the jaw. According to Bourne (2002), a number of textural parameters were extracted from the resulting force–vs.-time curves, these generally correlating well with sensory evaluation. The force peak on the first ( $H_1$ ) or second ( $H_2$ ) compression cycle was defined as the cooked chickpea hardness at 25% deformation. The *cohesiveness* or *cohesion energy resilience* (CER) was defined as the ratio between the force-vs.-time areas during the second ( $AC_2$ ) and first ( $AC_1$ ) compression cycles, while the *cohesion force resilience* (CFR) as the ratio between  $H_2$  and  $H_1$ . Each TPA test was repeated five times. A subjective cookability test (*pinching test*) was also performed to assess empirically chickpea softness by pressing cooked chickpeas between the thumb and index finger. These were considered cooked if their cotyledons disintegrated upon pressing (Kinyanjui et al., 2015). According to Kwofie et al. (2020), seed softening was fitted using the following 2-parameter non-linear exponential regression equation:

$$H_1 = H_{10} \exp(-K_F t_c) \quad (1)$$

where  $H_1$  and  $H_{10}$  represent the instantaneous and initial peak forces on the 1<sup>st</sup> compression cycle,  $t_c$  is the cooking time, and  $K_F$  is the rate constant of seed softening.

All data collected were expressed in terms of mean value ( $\mu$ ) and standard deviation (sd). The Tukey's test was applied for the statistical comparison of means at the probability level ( $p$ ) of 0.05.

Table 1: Main chemico-physical properties of the Solco Dritto chickpeas as such (SDC), decorticated (DSDC) or malted (MSDC).

Chemico-Physical property	SDC	DSDC	MSDC	Unit
Raw protein	22.3±1.7 <sup>a</sup>		23.6±1.9 <sup>a</sup>	g/100 g dm
Total Starch (TS)	46.8±0.6 <sup>a</sup>		45.2±2.0 <sup>a</sup>	g/100 g dm
Resistant Starch (RS)	1.77±0.22 <sup>a</sup>		1.19±0.43 <sup>a</sup>	g/100 g dm
Phytic Acid (PA)	1.15±0.03 <sup>a</sup>		0.79±0.09 <sup>b</sup>	g/100 g dm
Raffinose (R)	3.80±0.15 <sup>a</sup>		1.65±0.11 <sup>b</sup>	g/100 g dm
Seed weight ( $m_s$ )	0.302±0.010 <sup>a</sup>	0.228±0.001 <sup>b</sup>	0.219±0.002 <sup>c</sup>	g/seed
Seed volume ( $V_s$ )	0.233±0.012 <sup>a</sup>	0.205±0.023 <sup>a,b</sup>	0.191±0.000 <sup>b</sup>	cm <sup>3</sup> /seed
Mean seed radius ( $R_s$ )	0.382±0.006 <sup>a</sup>	0.365±0.014 <sup>a,b</sup>	0.358±0.000 <sup>b</sup>	cm/seed
Seed density ( $\rho_s$ )	1.30±0.09 <sup>a</sup>	1.13±0.12 <sup>b</sup>	1.14±0.01 <sup>b</sup>	g cm <sup>3</sup>
Hydration capacity (HC)	0.284±0.006 <sup>a</sup>	0.227±0.002 <sup>b</sup>	0.182±0.010 <sup>c</sup>	g/seed
Swelling capacity (SC)	0.503±0.015 <sup>a</sup>	0.394±0.013 <sup>b</sup>	0.369±0.012 <sup>b</sup>	cm <sup>3</sup> /seed
$L^*$	72.6±1.8 <sup>b</sup>	69.5±1.6 <sup>c</sup>	75.1±1.8 <sup>a</sup>	-
$a^*$	4.4±0.6 <sup>a</sup>	3.7±0.5 <sup>b</sup>	2.3±0.6 <sup>c</sup>	-
$b^*$	31.0±1.6 <sup>a</sup>	27.0±2.4 <sup>b</sup>	27.0±1.3 <sup>b</sup>	-

In each row, values with the same letter have no significant difference at  $p < 0.05$ .

### 3. Results and Discussion

#### 3.1. Physical properties

The chemico-physical properties of the chickpea seeds under study are listed in Table 1. Their seed weight ( $m_s$ ), volume ( $V_s$ ), hydration (HC) and swelling (SC) capacities were slightly smaller than those of several Sicilian strains (Patanè et al., 2004), but greater than some Indian cultivars of the Desi and Kabuli types (Kaur

et al., 2005). The density ( $\rho_s$ ) of the Indian chickpeas was like that of SDCs, but greater than that ( $1.18 \pm 0.15$  g/cm<sup>3</sup>) of the Sicilian seeds. Since swelling capacity and hydration capacities were found to be related to the cooking time in chickpeas (Williams et al., 1983), the cooking time of SDCs should fall within those of such Indian and Sicilian varieties. The crude protein, phytic acid and raffinose contents on a dry matter basis fell within the same range of several chickpea varieties (Frias et al., 2000; Rawal et al., 2019). There was a general reduction in the physical properties of decorticated and malted SDCs with respect to SDC as such. Moreover, the content of flatulence-inducing sugars or phytate in malted SDCs was reduced by about 57% or 31% with respect to the original ones, respectively. Finally, once splitted, all chickpea seeds were characterized by the CIELab color coordinates shown in Table 1. Their positive value of  $b^*$  indicated a yellow hue, but their difference in lightness  $L^*$  was found to be statistically significant at  $p=0.05$  (Table 1). Nevertheless, the color of SDCs as such, decorticated or malted was a light one quite near to the cream color ([//convertingcolors.com](http://convertingcolors.com)).

### 3.2. Chickpea softening

The softening of chickpeas upon cooking was monitored by performing several TPA tests as a function of the cooking time ( $t_c$ ). As an example, Figure 3 shows the main results of a 2-cycle TPA test performed with SDCs as such, presoaked in tap water for 16 h and cooked for 32 or 90 min.

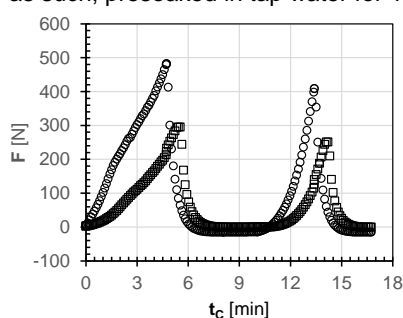


Figure 3: TPA testing using whole SDCs as cooked for 32 (○) or 90 min (□): Compression force vs. time.

Table 2 shows the effect of the cooking time ( $t_c$ ) on a few TPA parameters (i.e.,  $H_1$ ,  $A_{C1}$ ,  $A_{D1}$ ,  $H_2$ ,  $A_{C2}$ ,  $A_{D2}$ , CER, and CFR) of SDCs as such, decorticated, or malted. Firstly, the *cohesion force resilience* (CFR) exhibited quite an insignificant variation in the cooking time intervals tested at  $p<0.05$ , while the *cohesion energy resilience* (CER) showed a statistically significant variation around the optimal cooking time. The other textural parameters  $H_1$ ,  $A_{C1}$ ,  $A_{D1}$ ,  $H_2$ ,  $A_{C2}$ , or  $A_{D2}$  exponentially decreased as  $t_c$  increased, as shown for instance for  $H_1$  in Figure 4.

Table 2. Effect of the cooking time ( $t_c$ ) on the main TPA parameters ( $H_1$ ,  $A_{C1}$ ,  $A_{D1}$ ,  $H_2$ ,  $A_{C2}$ ,  $A_{D2}$ , CER, CFR) when using SDCs as such or decorticated, presoaked in water for 16 h, and malted, but unsoaked.

$t_c$ [min]	$H_1$ [N]	$A_{C1}$ [mJ]	$A_{D1}$ [mJ]	$H_2$ [N]	$A_{C2}$ [mJ]	$A_{D2}$ [mJ]	CER [-]	CFR [-]
<i>SDC presoaked in water for 16 h</i>								
20	495±17 <sup>a</sup>	1725±123 <sup>a</sup>	-284±36 <sup>a</sup>	422±13 <sup>a</sup>	586±44 <sup>a</sup>	-219±37 <sup>a</sup>	0.340±0.014 <sup>a</sup>	0.852±0.010 <sup>a</sup>
32	444±36 <sup>b</sup>	1460±203 <sup>b</sup>	-259±25 <sup>a,b</sup>	380±31 <sup>b</sup>	524±55 <sup>b</sup>	-205±20 <sup>a</sup>	0.360±0.014 <sup>a,b</sup>	0.856±0.010 <sup>a</sup>
45	388±33 <sup>c</sup>	1274±171 <sup>b,c</sup>	-226±24 <sup>b</sup>	330±27 <sup>c</sup>	463±46 <sup>b,c</sup>	-177±22 <sup>a,b</sup>	0.366±0.019 <sup>b</sup>	0.851±0.011 <sup>a</sup>
57	351±28 <sup>c</sup>	1116±140 <sup>c</sup>	-198±25 <sup>b,c</sup>	297±21 <sup>c</sup>	407±41 <sup>c</sup>	-155±21 <sup>b</sup>	0.365±0.012 <sup>b</sup>	0.846±0.011 <sup>a</sup>
75	293±20 <sup>d</sup>	873±87 <sup>d</sup>	-156±16 <sup>c,d</sup>	248±15 <sup>d</sup>	332±26 <sup>d</sup>	-120±13 <sup>c</sup>	0.380±0.012 <sup>b,c</sup>	0.847±0.014 <sup>a</sup>
90	262±32 <sup>d</sup>	765±126 <sup>d</sup>	-138±21 <sup>d</sup>	222±27 <sup>d</sup>	298±45 <sup>d</sup>	-107±17 <sup>c</sup>	0.390±0.010 <sup>c</sup>	0.847±0.006 <sup>a</sup>
<i>Unsoaked decorticated SDCs</i>								
20	469±51 <sup>A</sup>	1035±177 <sup>A</sup>	-286±38 <sup>A</sup>	405±44 <sup>A</sup>	490±72 <sup>A</sup>	-231±30 <sup>A</sup>	0.48±0.02 <sup>A</sup>	0.86±0.01 <sup>A</sup>
32	340±37 <sup>B</sup>	876±56 <sup>B</sup>	-232±35 <sup>B</sup>	345±35 <sup>B</sup>	402±48 <sup>A</sup>	-187±31 <sup>A</sup>	0.46±0.03 <sup>A</sup>	0.86±0.01 <sup>A</sup>
45	275±10 <sup>C</sup>	687±63 <sup>C</sup>	-137±2 <sup>C</sup>	229±7 <sup>C</sup>	267±8 <sup>B</sup>	-105±3 <sup>B</sup>	0.39±0.03 <sup>B</sup>	0.83±0.01 <sup>B</sup>
57	212±14 <sup>D</sup>	548±40 <sup>D</sup>	-97±14 <sup>D</sup>	176±12 <sup>D</sup>	207±21 <sup>C</sup>	-73±12 <sup>C</sup>	0.38±0.03 <sup>B</sup>	0.83±0.01 <sup>B</sup>
<i>Unsoaked decorticated and malted SDCs</i>								
20	459±28 <sup>α,A</sup>	1311±4 <sup>α</sup>	-312±3 <sup>α</sup>	413±0 <sup>α</sup>	558±3 <sup>α</sup>	-248±1 <sup>α</sup>	0.426±0.004 <sup>α</sup>	0.854±0.002 <sup>α</sup>
32	381±36 <sup>β,B</sup>	1151±36 <sup>β</sup>	-259±6 <sup>β</sup>	374±9 <sup>β</sup>	483±20 <sup>β</sup>	-210±5 <sup>β</sup>	0.419±0.004 <sup>β</sup>	0.859±0.002 <sup>β</sup>
45	280±41 <sup>γ,C</sup>	1159±54 <sup>β</sup>	-239±4 <sup>γ</sup>	343±5 <sup>γ</sup>	456±13 <sup>γ</sup>	-187±3 <sup>γ</sup>	0.393±0.007 <sup>γ</sup>	0.834±0.002 <sup>γ</sup>
57	238±29 <sup>δ,D</sup>	944±31 <sup>γ</sup>	-193±7 <sup>δ</sup>	296±4 <sup>δ</sup>	383±6 <sup>δ</sup>	-153±4 <sup>δ</sup>	0.406±0.007 <sup>δ</sup>	0.848±0.002 <sup>δ</sup>

In each column, values with the same Latin or Greek letter have no significant difference at  $p < 0.05$ .

Thus, the rate of chickpea softening was expressed by using Eq. (1). Table 3 shows the different least-squares empirical coefficients ( $H_{10}$ ,  $K_F$ ). Whereas both unsoaked decorticated SDCs and malted SDCs exhibited almost the same initial peak force ( $H_{10}$ ), the former exhibited a statistically significantly ( $p=0.05$ ) greater softening rate constant ( $K_F$ ) than the latter, the cookability of which being probably delayed by the kilning process performed.

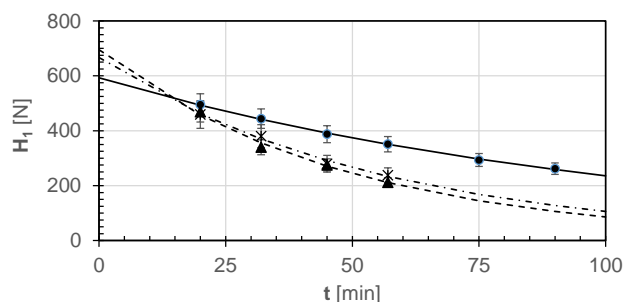


Figure 4: Effect of the cooking time ( $t_c$ ) on the experimental hardness  $H_1$  of presoaked SDCs as such ( $\bullet$ , —), or unsoaked decorticated ( $\blacktriangle$ , - - -) or malted chickpeas ( $*$ , — . —). The continuous, broken, and dash-dotted lines were plotted using Eq. (1) and the empirical coefficients reported in Table 3.

Table 3. Empirical least-squares softening coefficients of differently treated SDCs and corresponding coefficients of determinations ( $r^2$ ).

Chickpeas type	$H_{10}$ [N]	$K_F$ [ $\text{min}^{-1}$ ]	$r^2$
SDCs presoaked in water for 16 h	exp ( $6.39 \pm 0.01$ ) <sup>b</sup>	$-0.0092 \pm 0.0002$ <sup>c</sup>	0.998
Unsoaked decorticated SDCs	exp ( $6.54 \pm 0.06$ ) <sup>a</sup>	$-0.0209 \pm 0.0014$ <sup>a</sup>	0.991
Unsoaked decorticated malted SDCs	exp ( $6.50 \pm 0.06$ ) <sup>a</sup>	$-0.0140 \pm 0.0014$ <sup>b</sup>	0.989

In each column, values with the same letter have no significant difference at  $p < 0.05$ .

The Pinch Test appeared to be ineffective in assessing accurately the cooking time of chickpeas. All the samples cooked for longer than 20 min tended to disintegrate when pressed between the thumb and index finger (Figure 5). Actually, cooked chickpeas broke in small pieces as  $t_c$  increased from 20 to 32 min, while for  $t_c < 45$  min, once pressed, cooked chickpeas exhibited a certain degree of cohesion, being pasty and soft (Figure 5).

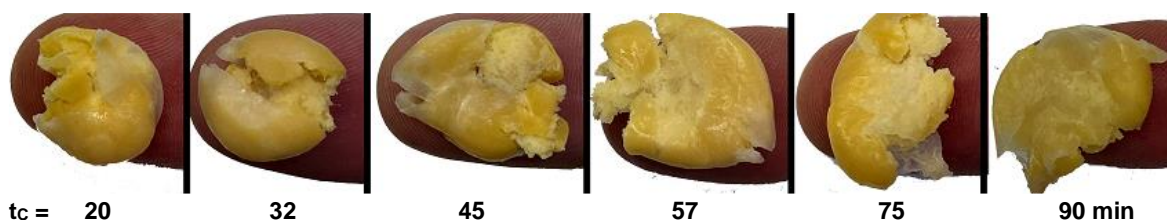


Figure 5: Pictures of presoaked SDCs as such submitted to the pinch test after cooking for 20 to 90 min.

Thus, the optimal cooking time for presoaked SDCs as such or unsoaked decorticated SDCs was around 75 or 45 min, respectively. About 45 min were found to be sufficient to cook unsoaked malted SDCs.

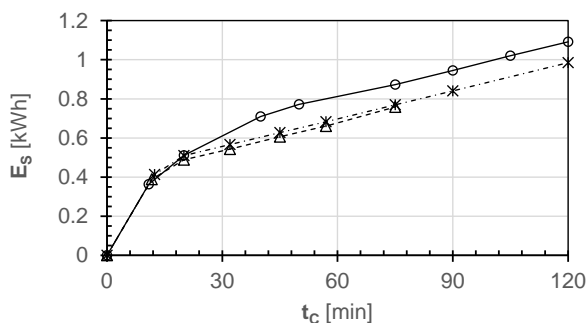


Figure 6: Electric energy ( $E_s$ ) supplied by the induction hob when cooking about 750 g of presoaked SDCs as such ( $\circ$ ), unsoaked decorticated SDCs ( $\triangle$ ), or unsoaked decorticated malted SDCs ( $*$ ).



### 3.3. Seed cooking energy and moistening rate

Figure 6 shows the time course of the electric energy ( $E_s$ ) supplied by the induction hob when about 750 g of SDCs were cooked at 98 °C using a water-to-chickpea ratio of 4 g/g. By accounting for the above optimal cooking times, the electric energy needed to cook 1 kg of presoaked raw SDCs would be ~1.26 kWh, while it dropped to 0.81-0.84 kWh in the case of 1 kg of unsoaked decorticated SDCs as such or malted.

## 4. Conclusions

Germinated, dried and dehulled *Solco Dritto* chickpeas exhibited not only about 57% and 31% lower contents in the flatulence-inducing sugars and phytate than the raw counterpart, respectively, but also a shorter cooking time with no presoaking need. Thus, the malting process of SDCs converted such legumes into a real convenience food assisting the general consumer with shorter preparation times and more healthy and sustainable eating habits. Further work is needed to assess the acceptability of malted chickpea cotyledons by sensory analysis, as well as the effect of kilning operating conditions on malted chickpea softening rate.

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