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Is Pasta Cooking Quality Affected by the Power Rating, Water-to-Pasta Ratio and Mixing Degree?

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In this work, the main chemico-physical cooking quality of commercial spaghetti was evaluated using two typical home gas- or electric-fired hobs by setting the cooking water-to-pasta ratio (WPR) and power supplied (P_C) during the pasta cooking phase in the presence or absence of stirring at 3 or 10 L kg^{-1} and 0.15 or 1.0 kW, respectively. The average values of cooked pasta water uptake (1.3±0.1 g g^{-1}), cooking loss (38±4 g kg^{-1}), degree of starch gelatinization (12±1 %), hardness at 30 % (6.0±0.4 N) or 90 % (15±1 N) deformation, and resilience (0.60±0.02) resulted to be practically constant and independent of the cooking system, WPR and P_C values used at the 95 % confidence level. The overall energy efficiency of the induction hob was about the double of that of the LPG-fired one. Moreover, at WPR=3 L kg^{-1} and P_C=0.25 kW, it was possible to cook spaghetti under mild mixing in no more than 15 min with a minimum energy consumption of 0.54 Wh g^{-1}, this amounting to about the 35 % of that consumed with the same sustainable cooking procedure at WPR=10 L kg^{-1}. The intermittent mixing degree at a rotational speed of 50 rev min^{-1} appeared to be sufficient at WPR=3 L kg^{-1}. The induction hob was thus eligible to develop a specialized appliance for pasta cooking.

1. Introduction

The energy used in food cooking may represent the foremost share of the energy consumed during the whole food life cycle (Carlsson-Kanyama and Boström-Carlsson, 2001; Xu et al., 2015). Dry pasta is generally cooked in boiling water, such a temperature being required to enhance convective motions within the water-paste suspension and thus increase heat and mass transfer from the bulk to the pasta surface throughout the cooking phase (Piazza et al., 1994; Sicignano et al., 2015). Pasta mixing during cooking is crucial to yield a homogeneously cooked product without agglomerates and/or partly cooked areas.
The pasta cooking energy needs are dependent on the home appliance and cooking water-to-pasta ratio (WPR) used. The overall energy efficiency (η_C) of dried pasta cooking using gas-fired and induction hobs was found to vary from 30 to 46 %, respectively, the latter being the most efficient cooking system. Its usage in conjunction with an environmentally sustainable pasta cooking practice previously set up resulted in quite limited water evaporation and a carbon footprint of 0.67±0.04 kg of carbon dioxide equivalents per kg of dry pasta (Cimini and Moresi, 2017). Greater energy saving was achieved by reducing WPR from the typical values of 10-12 L kg^{-1} to as low as 2 L kg^{-1}, the spaghetti chemico-physical cooking quality being no statistically affected (Cimini et al., 2019c). At WPR equal to 10 or 3 L kg^{-1}, no difference in the sensory attributes of firmness, stickiness, bulkiness, and overall spaghetti cooking quality was also observed (Cimini et al., 2019a). In principle, cooked pasta quality might also be influenced by the power supplied during its cooking. The smaller the power rating the smaller the evaporated water fraction becomes. As the convective mixing in the pan reduces, there is a decrease in the overall water transfer coefficient from the bulk to the spaghetti surface and water rehydration rate in the spaghetti undergoing cooking.
The aim of this work was to assess how the chemico-physical cooking quality (i.e., cooked pasta water uptake, cooking loss, degree of starch gelatinization, hardness, and resilience) of a big-brand commercial pasta was affected by the power supplied (P_C) during pasta cooking when using two typical home gas- and electric-fired hobs at WPR equal to 10 or 3 L kg^{-1} in the absence or presence of stirring, respectively.

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2. Materials and Methods

Durum wheat semolina spaghetti no. 5 (Barilla G. e R. F.lli SpA, Parma, Italy) of the same production lot (n. E156528), packed in 0.5-kg paperboard boxes and purchased in a local supermarket, were used. Cimini et al. (2019c) reported their main geometric characteristics and composition.
The pasta cooking system consisted of a 3-L pan, a 2-kW 190-mm induction hob or a 2.2-kW camping stove (Campingaz Camp Bistrò, Camping Gaz Italia srl, Lonato del Garda, Italy) fed with a 220-g LPG cylinder, a digital scale, a non-magnetic stainless steel S-shaped impeller driven by a mixer EURO-ST P CV (IKA®-Werke GMBH, Staufen, D), a piezo-buzzer, and a custom-made data logger based on an Arduino Nano 3.0 (ATmega328) board (Cimini and Moresi, 2017; Cimini et al., 2019ac), as shown in Figure 1.

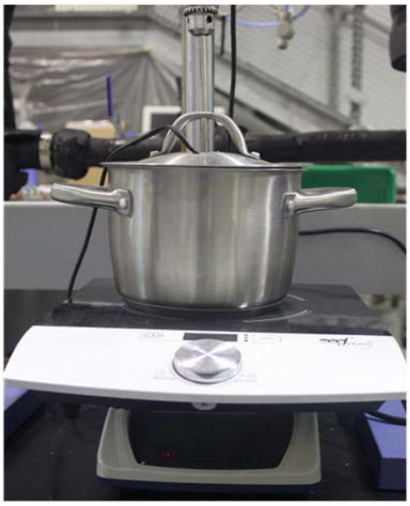

Figure 1: Picture the cooking system used in this work, consisting of a pan closed with its lid, mixer, thermocouple, and induction hob, both being placed over a technical balance

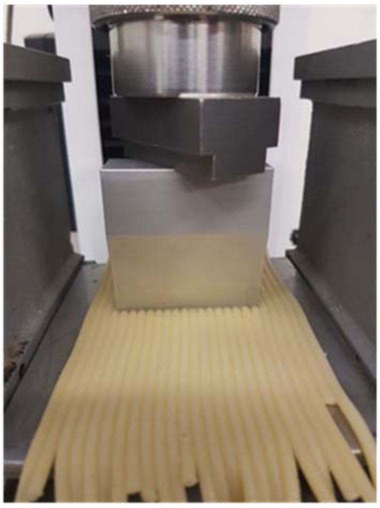

Figure 2: Picture of the cutting probe used to perform the Texture Analysis of 17 strands of cooked spaghetti aligned over a Teflon compression platen.

As the pan was filled with a given amount (m_{W0}) of cooking water at (20±1) °C and closed with its lid, both hobs were set at their maximum nominal power setting to bring rapidly the cooking water to the boiling point (Cimini and Moresi, 2017). The amount (m_{PA}) of dried pasta used was calculated as reported before (Cimini et al., 2019c). Each sample was weighed, broken in half, and cooked in boiling deionized water (Cimini et al., 2019c). As water had restarted to boil, the hob control knob of the induction hob was adjusted to four different nominal power ratings ($P_{C,nom}$=0.8, 0.6, 0.4, or 0.2 kW), while that of the LPG-fired hob was roughly regulated at the minimum or medium rating. The lid was closed, and the cooking temperature at about the atmospheric pressure was kept around 98 °C for as long as 9 min. The energy supplied by the induction hob (E_{SI}) was measured using a digital power meter type RCE MP600 (RCE Srl, Salerno, Italy), while that provided by the gas burner (E_{SG}) was assumed as coinciding with the heat released by the complete combustion of the mass (m_{LPG}) of LPG fuel consumed times its corresponding lower heating value (46 kJ g^{-1}: ADEME, 2007). Several blank tests were carried out with the gas control knob set at the maximum, medium or minimum level to measure the mass of the LPG cylinder as a function of time, and thus estimate m_{LPG} and E_{SG}. To avoid spaghetti sticking together during cooking at WPR=3 L kg^{-1}, the aforementioned stirrer was kept rotating at SR=50 or 75 rev min^{-1} for 1 min and resting for the subsequent minute (Cimini et al., 2019c).
The AACC International method 66-50.01 (1999) was used to monitor the central white core of spaghetti during cooking up to its disappearance. Cooking loss (CL) and water uptake (WU) by cooked pasta were determined in accordance with D'Egidio et al. (1990), while the degree of starch gelatinization (SGD) was colorimetrically measured according to Cocci et al. (2008). The texture analysis (TA) of cooked pasta was carried out using the Universal Testing Machine UTM mod. 3342 (Instron Int. Ltd., High Wycombe, UK) equipped with a 1000-N load cell (Cimini et al., 2019c). Seventeen strands of cooked spaghetti were placed over a stainless steel compression platen and tested using a stainless steel cutting probe (Figure 2) to measure the cooked spaghetti hardness on the first and second compression cycle at 30% (F_{30}) and 90% (F_{90}) deformation, and its resilience (CPR). The latter was defined as the force-vs-time area during the 1st withdrawal of the compression (A_D) divided by the force-vs-time area of the 1st compression (A_C). Each TA test was repeated five times. To check for the cooking water balance, its mass was measured at the beginning of

the cooking process (m_{W0}) and at its end when cooked pasta (m_{CPA}) was separated from residual cooking water or pasta water (m_{Wf}) using a colander. The mass of water adsorbed by pasta (m_{WPA}) and that of water totally evaporated (m_{We}), as well as their relative fractions (η_{Wi}) with respect to m_{W0}, were estimated as:

$$m_{WPA} = m_{CPA}-m_{PA} \quad (1)$$

and

$$m_{We} = m_{W0}-m_{Wf}-m_{WPA} \quad (2)$$

The energy efficiency (η_C) of each hob was estimated by relating the energy needed to cook dry pasta (E_{th}) to that supplied (E_{Si}), as reported by Cimini et al. (2019c). Each cooking test was replicated 2-4 times. Each parameter was shown as average±standard deviation and analyzed by Tukey test at a probability level of 0.05.

3. Results and Discussion

3.1 Effect of cooking time on cooked pasta TA parameters

To measure quantitatively cooked pasta quality, several TA tests were preliminarily carried out to assess the sensitivity of TA parameters towards the cooking time (t_C). The cooking water-to-dried pasta ratio was set at 12 L kg^{-1}, while the induction hob was managed in accordance with the environmentally sustainable pasta cooking practice recommended previously. Thus, the cooking water was heated at the maximum power setting (~2 kW), while dry pasta was cooked at the nominal power of 0.4 kW (Cimini and Moresi, 2017).
Table 1 shows the TA parameter values as a function of t_C in the range of 2 to 20 min.

Table 1: Effect of cooking time (t_C) on the mean values and standard deviations of the main TA parameters (F_{30}, A_C, A_D, CPR, and F_{90}) of spaghetti cooked in 12 L of water per kg of dry pasta with the hob control knob set at the nominal power rating of 2 kW or 0.4 kW during the water heating phase or pasta cooking one, respectively. Each test was repeated n times.

t_C [min]	n	F_{30} [N]	A_C [mJ]	A_D [mJ]	CPR [-]	F_{90} [N]
2	5	21±1	5.5±0.1	1.47±0.13	0.27±0.02	84±1
6	5	9.6±0.3	3.2±0.1	1.56±0.04	0.49±0.02	18±2
9	10	5.6±0.4	1.7±0.2	1.1±0.1	0.64±0.02	13.8±0.5
10	5	5.4±0.2	1.88±0.07	1.20±0.06	0.64±0.02	13.7±0.6
16	5	3.8±0.1	1.42±0.03	0.97±0.01	0.69±0.01	11.5±0.4
20	5	2.5±0.3	0.99±0.10	0.75±0.07	0.76±0.01	10.5±0.5

As t_C progressed, the hardness of cooked spaghetti strands submitted to cyclic compression up to the 30% (F_{30}) or 90% (F_{90}) of their initial diameter exponentially reduced from about 21 or 84 N to 2.5 or 10.5 N, respectively. On the contrary, the cooked pasta resilience (CPR) increased from 0.27 to 0.76 owing to the progressive protein coagulation and interactions that caused the formation of a continuous and reinforced network within which starch granules were trapped. In fact, a perfectly elastic body presents unitary resilience. For t_C>6 min, F_{30} and F_{90} tended to different asymptotic values. Figure 3 shows the progressive disappearance of the spaghetti central white core. After 4 min, a spaghetti strand as pressed between two Plexiglas plates exhibited three concentric zones (Sicignano et al., 2015). The external area appeared to be slightly swollen, the middle one denser and the inner one even more compact, probably due to lower levels of hydration and degree of starch gelatinization (Figure 3a). After 7 (Figure 3b) or 9 (Figure 3c) min, there was no significant variation in the appearance of pressed spaghetti, except in the larger diameter of the central white core. After 12 min, the three concentric zones appeared severely pulped, probably because the sample had been excessively cooked (Figure 3d). All subsequent tests were thus prolonged for just 9 min, as recommended by the pasta manufacturer.

3.2 Effect of the power supplied during pasta cooking and mixing degree on pasta cooking quality

Figure 4 shows the time (t) course of the thermal (E_{SG}) or electric (E_{SI}) energy supplied by the LPG-fired or induction hob during a few water heating tests performed with the control knob set at different power ratings. At the maximum nominal power rating, the pasta cooking tests were compromised by the formation of an intense thrust of water vapor bubbles that made the cooking water flow out of the pan.

Tables 2 and 3 show the main results of the cooking tests performed with the two home appliances examined. Generally, the time needed to heat water up to ~98 °C increased with WPR, but decreased as P_C was augmented. It ranged from 5.4 to 6.2 min or from 7.7 to 9.1 min when using the induction or LPG-fired hob.

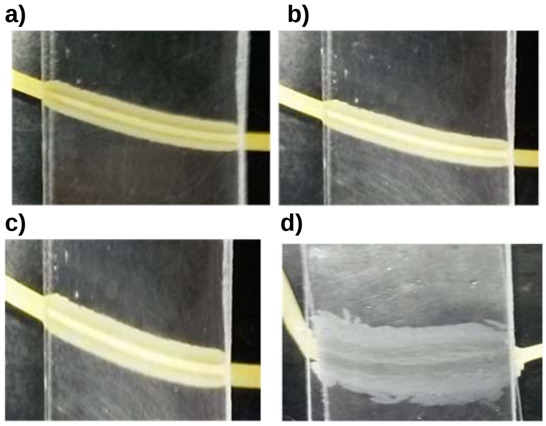

*Figure 3: Pictures of a spaghetti strand as removed from the pan at different cooking times of 4 (**a**), 7 (**b**), 9 (**c**), and 12 (**d**) min, and squeezed between two glass plates according to AACC International (1999).*

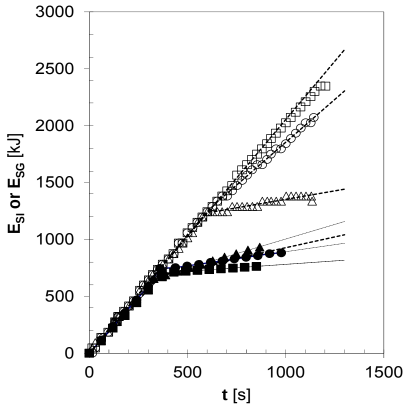

Figure 4: Water heating tests carried out by setting the control knob of the induction- (closed symbols) or LPG-fired (open symbols) hob initially at the maximum level and then to other nominal levels (▲, 0.2 kW; ●, 0.4 kW; ◆, 0.6 kW; ▲, 0.8 kW; □, 2.07 kW; ○, 1.5 kW; △, 0.3 kW): Energy supplied (E_{SI} or E_{SG}) vs*. time (t).The broken lines represent the least squares regressions.*

The overall energy efficiency (η_C) was negatively affected by P_C for both stoves, their coefficients of determination r^2 being greater than 0.91. It reduced from 72 to 56 % as P_C was increased from 0.15 to 0.52 kW for the induction hob, and from 46 to 35% as P_C was augmented from 0.2-0.3 to 1.0 kW for the gas-fired one. Such an energy efficiency loss depended on the amount of water uselessly evaporated. In fact, the fraction of water evaporated (η_{We}) increased with P_C or decreased with WPR (r^2=0.92). Obviously, the highest η_{We} value of 16 % was observed at the greatest P_C supplied (~1 kW). On the contrary, the fraction of water adsorbed by cooked spaghetti (η_{WPA}) was negatively related to WPR only (r^2=0.99). It was equal to 13-15 % of the initial amount of cooking water (m_{W0}) at WPR=10 L kg^{-1}, and increased to 42-45 % at WPR = 3 L kg^{-1}.
Altogether, whatever the hob used, the specific energy consumed to cook spaghetti (e_{PA}) was linearly correlated to WPR (r^2=0.91). As WPR was set at 3 or 10 L kg^{-1}, e_{PA} ranged from 0.5 to 1.8 Wh g^{-1} when using the induction hob (Table 2), and from 0.8 to 2.5 WP Wh g^{-1} when using the LPG-fired one because of its smaller energy efficiency (Table 3).
As concerning the quality of cooked pasta, the water uptake (WU), cooking loss (CL) and starch gelatinization degree (SGD) were firstly affected by WPR and then by PC, their corresponding coefficients of determination being approximately equal to 0.90. The average values of WU (1.3±0.1 g g^{-1}), CL (38±4 g kg^{-1}), and SGD (12±1 %) resulted to be practically independent of the cooking hob used at the confidence level of 95%. Such a behavior was also observed for the TA parameters examined (F_{30}, F_{90} and CPR), their coefficients r^2 ranging from 0.85 to 0.88. Similarly, since the experimental values of F_{30} (6.0±0.4 N), F_{90} (15±1 N), and CPR (0.60±0.02) did not significantly differ when varying the cooking system, or WPR and P_C, the textural quality of cooked spaghetti was retained approximately constant. As shown in Table 1, as t_C increased from 6 to 10 min F_{30} and F_{90} reduced at a rate of about 1 N min^{-1} and any difference in F_{30} and F_{90} of the order of 0.5 N exerted a negligible effect on the chemical quality of cooked pasta (i.e., CL, WU, SGD). The smaller the amount of cooking water, the greater the decrease in water temperature after dry pasta addition became. Even if the control knob of the induction hob was kept at its maximum rating to re-heat the pasta-water mixture up to the boiling point, at the lower WPR examined here the spaghetti tended to sink to the pan bottom and start to lump and stick together. At WPR=3 L kg^{-1}, an intermittent mild mixing at SR=50 rev min^{-1} was found to be sufficient to avoid spaghetti sticking to each other if the power supplied by the induction hob was about 0.25 kW. At P_C≈0.15 kW, spaghetti stayed stuck one another even if the mixer was kept operating continuously at SR=50 or 75 rev min^{-1}. Moreover, the results of TA tests were quite unexpected. For instance, the observed F_{90} values displayed a range of variation of 2.8 N, definitively larger than that usually observed (0.2-0.3 N). In these operating conditions, there was a great difficulty of unravelling the bundle of spaghetti. The numerous entanglements had the effect of increasing the apparent viscosity of the suspension, this impairing the efficacy of the stirring system used. At WPR=3 L kg^{-1}, the electric power absorbed by the mechanical stirrer was

6.1±0.5 W. By referring to an amount of raw pasta of ~406 g and a running time of 4.5 min out of an overall cooking time of 9 min, the specific stirring energy consumed (0.0011 Wh g^{-1}) was negligible with respect to e_{PA}.

Table 2: Spaghetti cooking tests with the induction hob at different values of $P_{C,nom}$, WPR and SR: water boiling time (t_H); effective power supplied (P_H, P_C); overall cooking energy (E_{ST}) and efficiency (η_C); specific energy consumed (e_{PA}); fractions of water evaporated (η_{We}), adsorbed by cooked pasta (η_{WPA}) and remaining as pasta water (η_{Wf}); relative water uptake (WU); cooking loss (CL); starch gelatinization degree (SGD), and main TA parameters (F_{30}, F_{90}, CPR). Different lowercase letters indicate statistically significant difference among the row means of each parameter at p=0.05.

Parameter		Values						
$P_{C,nom}$	[kW]	0.2[a]	0.4[b]	0.4[b]	0.6[c]	0.6[c]	0.8[d]	0.8[d]
WPR	[L/kg]	10.0±0.0[a]	10.02±0.03[a]	3.0±0.0[b]	10.03±0.03[a]	3±0[b]	10.02±0.01[a]	3±0[b]
SR	[rev s^{-1}]	0	0	0.833	0	0.833	0	0.833
m_{W0}	[g]	1477.3±0.4[a]	1477±5[a]	1218.5±0.1[b]	1477.7±0.[a]	1219.1±0.1[b]	1478±0[a]	1219±1[b]
m_{PA}	[g]	147.4±0.3[a]	147.6±0.3[a]	406±0[b]	147.3±0.4[a]	406.4±0.2[b]	147.5±0.2[a]	406.5±0.2[b]
P_H	[kW]	1.85±0.01[a]	1.83±0.01[b]	1.96±0.01[c]	1.92±0.05[d]	1.92±0.05[d]	1.86±0.02[a]	1.89±0.06[f]
t_H	[min]	6.2±0.1[a]	6.0±0.3[a]	6.1±0.1[a]	5.85±0.46[a]	5.71±0.47[a]	6.13±0.02[a]	5.37±0.14[b]
P_C	[kW]	0.15±0.01[a]	0.24±0.01[b]	0.25±0.01[c]	0.37±0.01[d]	0.39±0.02[e]	0.51±0.02[f]	0.52±0.01f
η_C	[%]	72±1[a]	70±2[a]	65±1[b]	60±5[b]	62±1[b]	56±1[c]	58±1[c]
E_{ST}	[W h]	214±3[a]	225±3[b]	222±2[b]	252±6[c]	243±1[d]	271±3 [e]	257±4[c]
$e_{C,eff}$	[W kg^{-1}]	89±3[a]	145±4[b]	153±7[c]	228±8[d]	240±9[e]	316±15[f]	320±5[f]
e_{PA}	[Wh g^{-1}]	1.45±0.02[a]	1.52±0.02[b]	0.54±0.01[c]	1.71±0.03[d]	0.60±0.01[f]	1.84±0.02[g]	0.63±0.01[h]
η_{WE}	[%]	5±2[a]	3.0±0.3[a]	6.6±0.6[a]	5.8±0.7[a]	9±2[b]	8±3[b]	10.3±0.3[b]
η_{WPA}	[%]	13.0±0.1[a]	15.2±0.3[b]	42.2±0.1[c]	13.7±0.8[a]	43±2[c]	13.6±0.4[a]	43±1[c]
η_{Wf}	[%]	83±3[a]	82±1[a]	51±1[b]	81±1[a]	48.4±0.5[c]	79±1[a]	47±1[c]
WU	[g g^{-1}]	1.30±0.01[a]	1.53±0.03[b]	1.27±0.00[c]	1.37±0.01[d]	1.28±0.05[e]	1.36±0.4[d]	1.29±0.02[e]
CL	[g kg^{-1}]	36±2[a]	42±1[b]	35±1[a]	42±1[b]	37±1[a]	35±2[a]	36±1[a]
SGD	[%]	9.6±0.6[a]	11.3±2.0[b]	11.5±0.4[b]	11.8±0.1[b]	11.1±0.4[b]	11.0±0.1[b]	12±1[b]
F_{30}	[N]	6.3±0.3[a]	6.4±0.4[a]	6.1±0.3[a]	6.1±0.2[a]	6.2±0.4[a]	5.8±0.3[a]	6.6±0.3[a]
F_{90}	[N]	15±1[a]	15.4±09[a]	15.1±1.2[a]	15.2±0.9[a]	15.9±0.8[a]	14.8±0.8[a]	16.1±0.9[a]
CPR	[-]	0.60±0.02[a]	0.61±0.02[a]	0.60±0.01[a]	0.60±0.02[a]	0.58±0.01[d]	0.61±0.01[a]	0.58±0.01[d]

- Different lowercase letters indicate statistically significant difference among the row means of each parameter at p=0.05.

Table 3: Spaghetti cooking tests with the LPG-fired hob at different values of $P_{C,nom}$, WPR and SR: same parameters listed in Table 2.

Parameter		Values			
$P_{C,nom}$	[kW]	min	min	medium	medium
WPR	[L/kg]	10.0±0.0[a]	3.0±0.0[b]	10.03±0.01[a]	3±0[b]
SR	[rev s^{-1}]	0	0.833	0	0.833
m_{W0}	[g]	1477.6±0.3[a]	1219.0±0.1[b]	1477.6±0.4[a]	1218.2±0.1[b]
m_{PA}	[g]	147.4±0.2[a]	406.2±0.1[b]	147.4±0.1[a]	406.6±0.1[b]
P_H	[kW]	2.07±0.00[a]	2.07±0.00[a]	2.07±0.00[a]	2.07±0.00[a]
t_H	[min]	9.06±0.02[a]	7.85±0.00[b]	9.05±0.04[a]	7.65±0.07[c]
P_C	[kW]	0.31±0.05[a]	0.21±0.08[b]	1.0±0.2[c]	0.99±0.06[c]
η_C	[%]	45.7±0.8[a]	44.9±0.4[a]	35±2[b]	35±1[b]
E_{ST}	[W h]	370±7[a]	338±10[b]	485±25[c]	453±11[c]
$e_{C,eff}$	[W kg^{-1}]	189±37[a]	129±49[b]	641±97[c]	611±35[c]
e_{PA}	[W h g^{-1}]	2.51±0.05[a]	0.83±0.02[b]	3.3±0.2[c]	1.11±0.03[d]
η_{WE}	[%]	3.9±0.9[a]	4±1[a]	12.1±0.5[b]	16±2[c]
η_{WPA}	[%]	13.4±0.4[a]	40±4[b]	13.4±0.2[a]	45±1[b]
η_{Wf}	[%]	82.7±0.5[a]	56±5[b]	74.5±0.7[c]	39±3[d]
WU	[g g^{-1}]	1.34±0.04[a]	1.2±0.1[b]	1.34±0.02[a]	1.34±0.03[a]
CL	[g kg^{-1}]	45.8±0.2[a]	32±12[b]	43.3±0.5[c]	34.8±0.1[b]
SGD	[%]	12.8±0.1[a]	11.0±0.4[b]	12.7±0.5[a]	12.7±0.3[a]
F_{30}	[N]	5.8±0.2[a]	6.0±0.3[a]	5.8±0.2[a]	5.8±0.2[a]
F_{90}	[N]	15.8±0.5[a]	15.2±0.8[a]	16.2±0.8[b]	15.0±0.6[a]
CPR	[-]	0.60±0.01[a]	0.58±0.01[b]	0.59±0.01[a]	0.58±0.01[b]

- Different lowercase letters indicate statistically significant difference among the row means of each parameter at p=0.05.

In principle, the aforementioned minimum P_C value should also depend on the pasta size. In particular, formats characterized by a greater external surface-to-volume ratio (i.e., spaghetti with an average diameter of 2 mm) than that of rigatoni or helicoidal with an outer diameter of 15-19 mm are generally more liable to come across and adhere to each other (Cimini et al., 2019b). Such occurrence had little bearing in the case of high WPRs (10-12 L kg^{-1}) and power ratings, as observed in the cooking tasks of the so-called hurried consumers (DeMerchant, 1997) or university students (Oliveira et al., 2012).

4. Conclusions

Pasta cooking is an energy-intensive process. Its energy efficiency might be improved by reducing simultaneously the cooking water-to-dry pasta ratio and effective power supplied during the so-called pasta cooking phase. The induction hob was found to be much more efficient than the LPG-fired stove and, what is more, by far easier to be finely regulated. By reducing WPR to 3 L kg^{-1} and P_C to 0.25 kW, it was possible to cook spaghetti under mild mixing at SR=50 rev min^{-1} in no more than 15 min with a minimum energy need of 0.54 Wh g^{-1}. By resorting to the LPG-fired hob and operating approximately under the aforementioned conditions, an extra cooking time of about 2 min was required with more than one and a half energy consumption. The chemico-physical quality of cooked pasta was almost insensitive to the cooking system used. In conclusion, by applying the eco-sustainable cooking procedure with the induction hob, it would be possible to reduce the energy consumed by 65 % and, consequently, the GHGs emitted to sustain the current Italian consumption of dry pasta. Further work is thus required to develop a specialized appliance to cook pasta.

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