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Short Communication

Influence of the brewing temperature on the taste of espresso

Johanna A. Klotz [1], Gertrud Winkler [1] and Dirk W. Lachenmeier [2,*]

[1] University of Applied Sciences Albstadt-Sigmaringen, Department Life Sciences, Anton-Günther-Str. 51, 72488 Sigmaringen, Germany; johannaklotz@web.de (J.A.K.), winkler@hs-albsig.de (G.W.)
[2] Chemisches und Veterinäruntersuchungsamt (CVUA) Karlsruhe, Weissenburger Strasse 3, 76187 Karlsruhe, Germany; lachenmeier@web.de
* Correspondence: lachenmeier@web.de; Tel.: +49-721-926-5434

Abstract: Very hot (> 65 °C) beverages such as espresso were evaluated by the International Agency for Research on Cancer (IARC) as probably carcinogenic to humans. For this reason, research into lowering beverage temperature without compromising its quality or taste is important. For espresso, one obvious possibility consists in lowering the brewing temperature. In two sensory trials using ISO 4120:2004 triangle test methodology, brewing temperatures of 80°C vs. 128°C and 80° vs. 93°C were compared. From the tested levels, espresso brewed at the lowest temperature had the highest acceptance. However, most tasters were unable to distinguish between 80°C and 93°C. The results of these pilot experiments proof the possibility to decrease the health hazard of very hot beverages by lower brewing temperatures.

Keywords: coffee; espresso; hot beverages; temperature; esophageal cancer; sensory trial

1. Introduction

In 1991, coffee was first classified by the International Agency for Research on Cancer (IARC) as "possibly carcinogenic for humans" (group 2B), as there had been a connection to increased risk of bladder cancer [1]. This relationship could not be confirmed in later studies and coffee itself has been reclassified into group 3 as “not classifiable” in 2016. In the earlier studies, the influence of tobacco smoking had confounded the results of coffee consumption, because both behaviors often occur at the same time [2]. The infusion of mate (*Ilex paraguariensis*) was evaluated as "probably carcinogenic" (group 2A) in 1991 [3]. The significantly increased cancer risk may be based on the fact that mate is typically drunk very hot. Epidemiological studies show that the esophageal cancer risk is increased when mate is consumed very hot but not when cold [2,4]. Because of that, mate *per se* was included during the 2016 re-evaluation in group 3 similar to coffee *per se*. Animal experiments suggest that a carcinogenic effect occurs at a consumption temperature of 65 °C or higher, which was defined as “very hot” [2,5]. Also considering epidemiological evidence (e.g. [6,7]), consumption of very hot (>65°C) beverages independent of type were classified in 2016 as "probably carcinogenic to humans" (group 2A) [2]. Several studies published subsequently to the IARC monograph further strengthened the evidence between consumption of very hot beverages independent of type and increased esophageal cancer risk [8,9].

In order to avoid the risk of injury in the pharynx due to an excessively high temperature, hot beverages should not be consumed until they have cooled down [10]. In several studies, however, it has been observed that hotter consumption temperatures are often preferred [11]. In a study from southern Germany, the temperature at which coffee is perceived to be too hot was investigated. The consumption temperature of coffee preferred by consumers is 63 °C. The average pain threshold is 67 °C [12]. However, coffee is typically brewed and served at temperatures higher than 65°C [10,13].

Espresso is a coffee beverage that is usually drunk immediately after brewing and without milk addition that may lower its temperature [14]. For the extraction of espresso, the water temperature (brewing temperature), has the most significant influence. If the brewing temperature is too high, a

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higher amount of compounds will be extracted into the espresso and its taste will be strongly influenced. Therefore, a maximum brewing temperature of 92°C was suggested. At higher brewing temperatures, more bitter and more astringent substances are dissolved into the espresso and its sensory quality is impaired [15]. However, field research detected that temperatures are often set at much higher levels, probably because of unfounded fears about microbiological hazards [13,16,17]. Salamanca et al. confirmed that the bitterness and acidity of espresso is more pronounced at higher brewing temperatures [18]. In a study by Andueza et al., the brewing temperature was also described as the greatest influence on the quality of espresso [19].

With espresso, a lower consumption temperature can be achieved by lowering the brewing temperature. This study will examine whether a lower brewing temperature of espresso has a negative effect on its taste. Is it necessary to brew espresso very hot for an optimal aroma? Or can it also be brewed at lower temperatures to achieve a pleasant espresso aroma? In order to find answers to these questions, sensory trials are carried out to determine whether espresso brewed at 93 °C, for example, differs in taste from espresso brewed at 80 °C.

2. Materials and Methods

The basic study design was investigating a perceptible sensory difference between samples of two products using the forced-choice ISO 4120:2004 sensory analysis methodology "triangle test" [20].

Individuals were given three espresso samples (2 temperature low/1 temperature high or 2 temperature high/1 temperature low in randomized fashion) and asked to make the following decision: which of the three samples is different? They were additionally asked about the preference regarding typicity of espresso taste of the deviating sample. The test material for sensory analysis was espresso beans type Orphea (Maromas group, Tägerwilen, Switzerland). The espresso machine was model ECM Synchronika (Espresso Coffee Machines Manufacture GmbH, Neckargemünd, Germany).

In order to create the same conditions for each espresso extraction according to the Italian Espresso National Institute [21], 7 ± 0.5 g freshly ground coffee powder is weighed directly into the filter holder for each espresso. The coffee powder is distributed evenly in the filter carrier by vibration. Then a tamper with a contact pressure of 25 kg is used to press the resulting coffee powder cake. A fine balance placed under the espresso cup is used to ensure the correct quantity of espresso. To start the process, the coffee machine's brewing lever is turned over. Meanwhile, the balance and stopwatch are observed, and when an espresso quantity of 25 ± 2.5 g is reached, the brewing lever is raised again to stop. If the espresso quantity is below or above the limit, or if the extraction time is outside specification (25 ± 5 s), a new extraction attempt is started. Particular attention is paid to a consistently uniform preparation method for the sensory trials.

Preliminary tests detected a clearly visible change in color due to the differences in brewing temperature. With a brewing temperature of 80 °C, the espresso is very dark colored with foam on the surface. Espresso at the maximum temperature of 128 °C is rather light brown in color and its consistency as well as the appearance of the foam is also different. For this reason, precautions have to be taken to ensure that during the tastings the test persons do not detect the deviating sample by the existing color deviation. Therefore, a tasting chamber was set up, which prevents light from entering. In addition, two lamps with color-adjustable LED light sources were used. Each color was checked but only dark blue light, which shines directly into the cups, prevents optical differentiation of the samples. Furthermore, white lids were placed on the espresso cups. The tasters were allowed to only open the lid of one cup at a time, therefore making it impossible to visually compare the samples even when moving them. Before each sample is tasted, the corresponding lid is removed and then replaced.

To ensure that the two identical samples of each triplet actually have identical properties, an espresso extraction with 25 ± 2.5 ml each is divided between two cups. The deviating sample is also divided, the second sample is used for the next test. Since the coffee machine needs time to heat up or cool down to the desired brewing temperature, it is essential to keep the espresso warm on

heating plates until it is tasted, ensuring that all three samples have the same temperature. The test can only be started once the three espresso samples have been equilibrated to the same consumption temperature of approximately 55 °C for a sensory test. 24 persons participated in two triangular tests. These included a total of 20 women and 4 men from different age groups. In the first triangle test, it was tested whether an espresso brewed at 80 °C differs from an espresso brewed at 128 °C. In the second test, the minimum brewing temperature of 80 °C is compared with the setting of 93 °C.

Power calculations were based on the ISO 4120:2004 [20] protocol and on Schlich [22]. ISO 4120:2004 provides a baseline scenario in which testers are assumed to be able to discriminate with 50% accuracy. To achieve statistical significance at a level of 0.05 for both α-risk (probability of concluding that a perceptible difference exists when one does not) and β-risk (probability of concluding that no perceptible difference exists when one does), at least 23 assessors are needed. For statistical analysis, the results of the espresso discrimination tests were applied to the significance tables of the ISO 4120:2004 based on Meilgaard et al. [23].

3. Results

Of a total of 24 test subjects, 10 individuals identified the deviating sample in both sensory tests. As shown in Table 1, 15 out of 24 people detected a difference between the espresso samples of the first triangular test (80°C vs. 128°C). A total of 13 people indicated that the sample brewed at 80 °C has the more typical espresso taste. In the second test, espresso was compared at a brewing temperature of 80 °C with a brewing temperature of 93 °C. Of the 24 test persons, 11 answered this test correctly (table 1).

Table 1. Results of ISO 4120:2004 sensory analysis using triangle testing for differentiation of espresso prepared using different brewing temperatures.

Brewing temperature	No. of assessors	No. of correct responses	Significance [1]	LCI/UCI [2]
80°C vs. 128°C	24	15	yes (α = 0.01)	0.19/0.68
80°C vs. 93°C	24	11	no (α = 0.20)	-

[1] According to ISO 4120:2004 [20]. For the non-significant trial, the minimum number of correct answers to conclude that a perceptible difference exists (α = 0.05) would have been 13/24.

[2] Lower and upper 95% confidence intervals (LCI/UCI) for triangle tests calculated according to ISO 4120:2004 [20]. The limits can be interpreted as percentage of population that can perceive a difference between the samples [23].

4. Discussion

According to DIN EN ISO 4120, for a triangular test with a significance level of α = 0.05 and with a number of test persons of n = 24, there is a minimum number of correct answers for determining a perceptible difference of 13 persons. It can therefore be concluded that there is a perceptible difference in Test 1 between the espresso sample brewed at 80 °C and the one brewed at 128 °C on the basis of a triangular test.

For the second triangular test, however, since only 11 persons have correctly detected a difference in the triangular test, it is not statistically significant. Espresso brewed at 80 °C is not distinguished from espresso brewed at 93 °C by taste. During the sensory analysis carried out in this work, hotter brewed espresso was described as stronger, more bitter and more acidic, similar to the study of Salamanca et al. [18]. Our results are comparable to Andueza et al. [19], while different methodologies were used. In the case of Andueza et al. [19], the espresso samples were extracted at brewing temperatures of 88 °C, 92 °C, 96 °C and 98 °C. It was found that more solids were detectable in espresso as the temperature rises. The tasting panel found the espresso more bitter and astringent when it was brewed at 96 °C and 98 °C [19]. Also in the study of Chapko & Seo, a too hot coffee temperature was described as roasted and burnt [24]. The results of the previous studies correlate with the feedback of the tasting panels in the sensory analysis carried out here.

It is not recommended to extract espresso beyond a brewing temperature of 93 °C. For the samples taken at the setting of the brewing temperature of 128 °C, there are only negative comments on the sensory attributes. They are burnt, bitter, and strongly acidic. The theoretical background is the higher the brewing temperature the more solids and less volatile substances can be dissolved in the espresso, resulting in a negative taste. As a result, more bitter and more astringent flavorings are dominant [15]. It is also interesting to note that the impression can be gained that espresso, which is produced at 80°C was more preferred in the tastings carried out. It is therefore even advisable to brew the espresso lower than the standard setting of around 90 °C. In this case, the risk of an excessively high consumption temperature can be completely avoided. It is interesting that the Italian Espresso National Institute suggests a temperature of 88 ± 2°C [21], which is a lower and stricter setting than what Illy and Viani are suggesting (90 ± 5°C) [15]. However, in practice, at least in many espresso bars in Germany, much higher settings appear to be in common use [13].

5. Conclusions

During the sensory examination it has been elucidated that espresso should not only be brewed less hot for health reasons. The espresso samples that were brewed at lower temperatures are more accepted by the tasting panel. At a brewing temperature of >120 °C, however, the espresso sample is described as undrinkable. For this reason, the coffee machine manufacturers should introduce adjustable brewing temperatures and suggest lower default settings in order to minimize the risk of esophageal cancer and to improve sensory perception. The guideline of the Italian Espresso National Institute, which allows brewing temperatures down to 86°C, but not over 90°C should be more widely implemented [21].

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