A Review of Hot Beverage Temperatures—Satisfying Consumer Preference and Safety

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Abstract: Hot beverages are served ubiquitously in the food-service industry as well as at residences and other venues. Coffee and tea beverages, in particular, are brewed at temperatures that are sufficiently high to cause immediate and serious risk for scald injuries. On the other hand, numerous research studies have been performed to identify the preferred consumption temperatures for hot beverages. The outcome of these mutually reinforcing studies is that the preferred drinking temperatures are significantly below the often-encountered brewing temperatures (~200 °F). Consequently, there is great need to distinguish brewing temperatures from serving temperatures. Serving consumers beverages at very high temperatures is not only unnecessary (from a preference standpoint) but also unsafe. An appropriate range for service temperatures is (130 to 160 °F).

Keywords: Burn, scald, hot beverage, injury

Practical Application: Often times, hot beverages are served at temperatures near their brewing temperature; far hotter than preferred by consumers. This practice creates unnecessary risk to the consumer. A more rationale recommended range of service temperatures is 130 to 160 °F. This recommendation balances a range of consumer preferences and safety.

Introduction

In the United States, numerous trade organizations in the beverage industry have recommended protocols for preparing hot beverages. Recommended temperatures vary by the type of beverage, but are often near boiling. For instance, the Specialty Coffee Association and the National Coffee Association of the USA recommends 195 to 205 °F. The Tea Association of the USA recommends relatively low temperatures (180 to 190 °F) for delicate teas such as oolongs and white tea but much hotter brewing temperature for black teas.

These and other organization recommendations may form the basis for an "industry standard" for preparing hot beverages. However, to the best knowledge of the authors, there are no guidelines for the service of hot beverages. Furthermore, research carried out in the academic community encourages lower brew temperatures (Lachenmeier & Schwartz, 2018)

In some instances, brewing temperatures are conflated with service temperatures so that consumers are presented with beverages that may be too hot for consumption. However, a continuing and reinforcing corpus of research has successfully articulated a preferred service temperature range for hot beverages. The recommended range is far below the brewing temperature recommendations. It is, therefore, appropriate to establish recommendations that conforms to both taste preference as well as consumer safety.

In the production of hot beverages, the heated water interacts with cool containers and environments that reduces its temperature. For coffee brewing, the hot water is passed over coffee grounds that begin at room temperature and into a carafe that is also often at room temperature initially. The temperature decrease during this process depends on the nature of the coffee equipment, the volume of heated water, the amount of coffee grounds that are used, the size and nature of the carafe, etc. It is estimated that a temperature decrease of ~3 °C (~5 °F) for large and insulated carafes but up to 20 °F for smaller, uninsulated glass carafes will occur during this process (Abraham et al., 2016). These estimates are based on multiple measurements made on commercially available brewing systems. It should be noted that there is a wide range of temperature change during this phase of the brewing process; the range depends strongly on the machine that is used for brewing. In this paper, the large/insulated systems will be focused on, partly because they are more commonly used than small household coffee makers (in commercial establishments). Also, because the risk of burns from small glass carafes is very low.

For tea, water is poured over room-temperature tea leaves and often into a room-temperature cup. These processes cause significant cooling to the liquid so that its temperature reduces somewhat. Heat loss occurs not only because the liquid enters a receptacle with lower wall temperature. Also, there are convective and evaporative heat losses that occur. Based on experiments carried out on multiple cup types, the temperature reduction of coffee and tea as it is poured into a cup is ~2 to 5 °C (4 to 9 °F) (Abraham et al., 2016).

With this background, it is possible to provide reasonable estimates of liquid temperatures at various stages in both coffee and tea brewing processes. Table 1 lists expected values, based on an initial brewing temperature of 200 °F (93 °C).

With these temperatures as a background, it is now appropriate to turn attention to published research on consumer preferences.

Methods

In an effort to bring together the relevant scientific literature on the issue of beverage service temperature and the effect on

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Table 1–Typical temperatures during the brew/service processes for coffee and tea.

Coffee		Tea	
Stage	**Temperature**	**Stage**	**Temperature**
Brewing	200 °F (93 °C)	Brewing	200 °F (93 °C)
Water exists grounds, into carafe	195 °F (90 °C)	Water poured into cup for service	191 to 196 °F (91 to 90 °C)
Water poured into cup for service	186 to 191 °F (85 to 88 °C)		

Table 2–Ranking of coffee temperatures (Borchgrevink et al., 1999).

Rank	Temperature °C (°F)
1	68.3 °C (155 °F)
2	62.8 °C (145 °F)
3	73.9 °C (165 °F)
4	57.2 °C (135 °F)
5	79.4 °C (175 °F)
6	85.0 °C (185 °F)
7	90.6 °C (195 °F)

Table 3–Ranking of coffee temperatures (Pipatsattayanuwong, Lee, Lau, & O'Mahoney, 2000).

Rank	Temperature °C (°F)
1	71.4 °C (161.8 °F)
2	60.9 °C (141.7 °F)
3	76.6 °C (169.8 °F)
4	49.8 °C (121.6 °F)
5	82.1 °C (179.8 °F)
6	39.2 °C (102.5 °F)

consumer preference and safety, an exhaustive literature search was performed. The result of that literature search is contained in the discussion that follows; they are arranged in chronological order.

Borchgrevink, Susskind, and Tarras (1999)

Among the first scientific studies that considered consumer-preferred beverage temperatures was Borchgrevink et al. (1999). There, 250 subjects from the USA were exposed to coffee at the following temperatures, 57.2 °C (135 °F), 62.8 °C (145 °F), 68.3 °C (155 °F) 73.9 °C (165 °F), 79.4 °C (175 °F), 85 °C (185 °F), and 90.6 °C (195 °F). The subjects were served the beverages in sequence and asked to rate the drink as "far too hot," "somewhat too hot," "just the right temperature," "somewhat too cold," and "far too cold." The top-ranked temperature was 68.3 °C (155 °F), followed by 62.8 °C (145 °F). Furthermore, beverages at temperature 79.4 °C (175 °F) and higher were considered at a minimum, "somewhat too hot." The overall ranking of beverage temperatures from this study is provided in Table 2.

Pipatsattayanuwong et al. (2001)

Pipatsattayanuwong et al. (2001) also studied black coffee and consumer preference. Those researchers ranked coffee by a hedonic index to allow comparison. 225 subjects, determined to be persons who regularly or occasionally drink black coffee, were recruited. Coffee was presented to the judges at six different temperatures. The coffee was Folgers Gourmet Supreme brand brewed using a Bunn Single and a Bunn-O-Matic brewing machine. The brewers delivered water in the range 82.1 to 91.4 °C (179.8 to 196.5 °F), with an average of 87.8 °C (190 °F). The brewed coffee was transferred to a holding container where it was mixed with cooler water to achieve the targeted temperature.

The order of preference from this study is provided in the summary list of Table 3. There, it is seen that the two most preferred temperatures are in the 61 to 72 °C (142 to 162 °F) range. The preferred temperatures agreed with those from Borchgrevink et al. (1999), adding confidence to the results.

Lee and Mahoney (2002)

In a near contemporaneous study, Lee and Mahoney (2002) recruited 300 customers to mix hot and cool coffees together to obtain their preferred temperatures. In this test, the consumers added sweeteners and creamer according to their taste preference. In a follow-on experiment, 108 subjects drank black coffee with different brew strengths. The preferred temperatures were recorded and ranked.

In the first experiment, 102 of the 300 subjects chose to drink black coffee, and the mean preferred temperature was 61.5 °C (142.7 °F). The remaining 198 subjects, those that used creamer and/or sweetener, had a mean preferred temperature of 59.0 °C (138.2 °F). The combined average of all 300 subjects for the first experiment was 59.8 °C (139.6 °F).

For the all-black coffee experiment, where the strength of coffee was varied, the mean preferred temperature for strong coffee was 59.3 °C (138.7 °F) whereas the preferred weak-black-coffee temperature was 60.4 °C (140.7 °F). These results provide further evidence that the preferred consumption temperature is much below that recommended for brewing.

Brown and Diller (2008)

An attempt to formally optimize beverage temperature was performed by Brown and Diller (2008). In that study, a figure of merit was used to simultaneously account for both preference and safety. As with earlier studies, this too focused primarily on coffee. The authors found that the optimum temperature range was approximately 54 to 60 °C (~130 to 140 °F) with a preferred value of 57.8 °C (136 °F).

Stokes, O'Sullivan, and Kerry (2016)

A recent study on the taste attributes of black coffee was performed by Stokes et al. (2016). Both aroma and flavor were investigated using ANOVA statistical methods. The experiments utilized a kettle with ~2 L of boiled water which was then used to brew coffee. Coffee was allowed to cool until various temperatures were achieved and then it was served to the subjects. Mean values of coffee samples ranged from 31 °C (87.8 °F) to 76.8 °C (170.2 °F). In total, 25 subjects were involved in the testing; the optimal temperature for black coffee was found to be 70.8 °C (159.4 °F). This finding confirms the earlier studies already discussed.

Dirler, Winkler, and Lachenmeier (2018)

The final study discussed here is Dirler et al. (2018). As with the prior investigations, consumers were presented with coffee at various temperatures. 87 subjects participated in the study and the

Table 4–Summary of most-preferred or recommended temperatures.

Study	Most-preferred/recommended temperature °C (°F)
Borchgrevink et al. (1999)	68.3 °C (155 °F)
Pipatsattayanuwong et al. (2001)	71.4 °C (161.8 °F)
Lee and Mahoney (2002)	59.8 °C (139.6 °F)
Brown and Diller (2008)	57.8 °C (136 °F).
Stokes et al. (2016)	70.8 °C (159.4 °F)
Dirler et al. (2018)	63 °C (145 °F)

mixing technique from Lee and O'Mahony (2003) was adopted. Both the preferred temperature and the pain threshold were noted. The averaged preferred drinking temperature was 63 °C (145 °F) with a range from 55 to 70 °C (131 to 158 °F). This range provides even further evidence of the consumer preference for beverages below the brewing temperature.

Discussion and Recommendations

In order to concisely summarize the above studies, Table 4 has been prepared. The table lists the most-preferred drinking temperature from each of the investigations.

It is noteworthy that all of these temperatures are far below the industry-group recommendations for brewing. This fact demonstrates that service temperatures need not be at brewing temperatures. Furthermore, when the added risk of injury is included in the decision, it adds further motivation for reducing temperatures.

It is well known that the rate of burn injury is very closely tied to temperature. In fact, the rate of injury increases very rapidly with each degree increase in the liquid temperature. Consequently, the temperatures listed in Table 4, which are ~40 to 50 °F below the recommended brewing temperatures will dramatically reduce injury risk. Extensive research has shown that spills which occur at higher temperatures (~180 °F) are very likely to cause at least mid-dermal burns which are very serious and often necessitate medical intervention (Abraham et al., 2016; Abraham, Plourde, Vallez, Stark, & Diller, 2015; Andrews, Kimble, Kempf, & Cuttle, 2017; Loo, Haider, Py, & Jeffrey, 2018). In addition, some populations (children and elderly for instance) are more at risk for injury because of their thinner skin, inability to move quickly after a spill incident, and smaller body size (Drago, 2005; Lowell, Quinlan, & Gottlieb, 2008; Ramanathan, Ekpenyong, & Stevenson, 1994).

Recent research has also tied hot-beverages to increases in cancer risk (for example, Islami et al., 2009, 2019; Loomis et al., 2016). So, there are risks to consumers aside from an acute burn injury.

It may be noted that the studies discussed here focus on coffee. It is expected that there would be similar preferred temperatures for other hot beverages (such as tea); we also expect that temperatures considered "too hot" for coffee would also be "too hot" for beverages such as tea. There may, however, be slight differences in the preferred consumption temperature for beverages other than coffee. Further research is warranted to investigate this issue. To the best knowledge of the authors, no scientific studies have been produced to study this issue.

With the importance of distinguishing brew temperatures and service temperatures, some commentary should be made about how establishments might reduce temperatures between brew and service. While an exhaustive set of recommendations is beyond the scope of this review article, a few suggestions are made for consideration.

Reduce holding temperatures, let beverages cool, or mixing

At many establishments, hot beverages are held at elevated temperatures in containers or carafes that have an external heat source. Coffee or tea is brewed with near-boiling water and then collected into the holding dispenser for later service. A simple means to reduce service temperature is to lower the holding temperature.

Another option is to allow beverages to cool between brewing and service in the cup. Fortunately, significant research has been performed on the rate of cooling of different beverages using various cup sizes, cup construction, and with/without caps. That research is presented in Abraham et al. (2016), Lachenmeier and Lachenmeier (2018), Mercer (1988), Jamnadas-Khoda et al., (2010), Warner, Wilson, and Chester (2012) and Okaru et al. (2018). Typically, temperatures drop ~10 to 15 °C (~20 to 25 °F) in a room environment in 5 min. The cooling rate depends on whether the upper surface of the beverage is exposed to the ambient or whether a cap is applied. The use of a cap approximately doubles the required cooling time. While it is beyond the scope of this paper to balance the economic or customer service costs of allowing some time for cooling, it is noteworthy that coffee brewed at the recommended brewing temperatures would be at or near the taste-preference temperatures after cooling for approximately 5 min.

A final option is to mixing very hot beverages with cooler beverages. Even small amounts of mixing can have significant effects. While a detailed discussion of mixing is beyond the scope of this review, from a thermal energy standpoint, any cool liquid would suffice. For instance, cooled coffee could be mixed into a hot, freshly brewed coffee to reduce temperature without dilution. Alternatively, milk, creamer, or other cooler liquids could be added as appropriate. This recommendation has been made in research publications, for instance, Verst, Winkler, and Lachenmeier (2018).

It is now possible to provide a recommendation to establishments for serving hot beverages. Those recommendations are listed in Table 5. First, it should be noted that a brewing temperature at the lower end of the recommended range is suggested (195 °F). Next, reasonable values of the temperature reduction as the brew process occurs have been incorporated. Some dilution, cooling, or a combination thereof is required as the final stage to reduce the temperatures to the recommended range. It is certain that establishments may have constraints or specific practices that may affect how they achieve the targeted temperature range. Also, brewing

Table 5–Recommended temperatures during the brew/service processes for coffee and tea.

Coffee		Tea	
Stage	**Temperature**	**Stage**	**Temperature**
Brewing	195 °F (91 °C)	Brewing	195 °F (91 °C)
Water exists grounds, into carafe	190 °F (88 °C)	Water poured into cup for service	186 to 191 °F (86 to 88 °C)
Water poured into cup for service	181 to 186 °F (83 to 86 °C)	After dilution or cooling	130 to 160 °F (54 to 71 °C)
After dilution or cooling	130 to 160 °F (54 to 71 °C)		

equipment is not monolithic, some variation exists between manufacturers and brands. However the cooling is accomplished, the result is a safer, and more satisfied consumer.

Concluding Remarks

Here, a review of the scientific literature has been made to assess the consumer-preferred temperatures for hot beverages. In order to balance both safety and consumer preference, temperatures in the range of 130 to 160 °F are recommended. Those temperatures are significantly below temperatures that are used during brewing processes. Consequently, conflating service temperatures with brewing temperatures is unnecessary and unsafe. Despite the variations among brewing equipment, at the completion of the brewing stages, liquid temperatures are almost certainly above the recommended values. In order to achieve the recommended values, some type of cooling or mixing is suggested.

Author Contributions

Both authors contributed to the conceptualization, writing, and editing of this manuscript.

Conflicts of Interest

Both authors have served in scald litigations. No other conflicts to declare.

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