EFFECT OF STORAGE CONDITIONS ON THE SENSORY QUALITY OF GROUND ARABICA COFFEE

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ABSTRACT

The objective of this study was to determine how long ground coffee beans could be stored at room and freezing temperatures before sensory changes could be detected, and to identify specific attribute changes associated with this storage. Ground beans were stored for 0 (fresh), 1, 2 and 3 weeks at room and freezing temperatures. Coffee was prepared from each of these treatments and difference testing was performed. Paired comparison tests were conducted on the fresh, 1- and 2-week-stored coffee grounds to examine the attributes of coffee aroma, flavor, bitterness and overall preference. At room temperature storage, results indicated significant ($P < 0.05$*) differences in the coffee prepared from fresh versus the 2-week-stored ground beans. Coffee made from freshly ground beans had a stronger coffee aroma, less bitterness and was more preferred compared with the beans stored for 1 or 2 weeks (*$P < 0.05$*). At freezer storage, differences were detected between coffee prepared from coffee grounds stored for 1 or 2 weeks. Coffee prepared from grounds stored for 2 weeks had a stronger coffee aroma and was more bitter compared with the other storage times (*$P < 0.05$*).*

INTRODUCTION

Ground coffee is one of the most widely consumed products and consequently is one of the world's principal commodities. As coffee is enjoyed for its unique flavor, its quality and consumer acceptability are dependent on its

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flavor and aroma profile. Because of the importance of flavor to the sensory acceptance of coffee, the aspects of flavor and aroma are well investigated (Semmelroch and Grosch 1996; Czerny *et al*. 1999; Mayer *et al*. 2000).

The preparation of quality coffee is composed of many stages including roasting and grinding of the coffee beans, as well as the final brewing of the coffee. Quality changes in coffee start to occur early in the coffee preparation process, resulting in the coffee's loss of the aroma and fresh flavor (Vila *et al*. 2005). These changes are referred to as staling and may be defined as a sweet but unpleasant flavor and aroma, resulting from the loss of many of the volatile compounds (Buffo and Cardelli-Freire 2004). In addition to volatile depletion, quality losses also result from the degradation of the coffee bean lipids by lipolysis and lipid oxidation (Vila *et al*. 2005). Because of the importance of freshness to coffee quality, the onset of sensory staleness is often used to determine the end of shelf life of roasted ground coffee (Cardelli and Labuza 2001).

Several studies have examined the effect of storage time on coffee quality. In one study, the shelf life of roasted and ground Arabica coffee was followed using consumer evaluations of product acceptability. The effects of the important shelf life factors of oxygen level, water activity and temperature were also examined (Cardelli and Labuza 2001). Product acceptability was measured using a modified Weibull hazard analysis method in which the end of shelf life was defined as the time at which 50% of the consumers deemed the product unacceptable. Higher levels of oxygen, water activity and temperature were all found to accelerate quality deterioration, resulting in reduced consumer acceptability of the resulting coffee. While this study did show the impact of a number of storage factors on the quality of stored coffee, specific attribute changes in the stored brewed coffee prepared from the stored ground coffee were not examined.

Interest in the shelf life of ground coffee is especially important to the consumer (Clarke 1993). Consumers may purchase whole beans for grinding at home or preground coffee at the point of purchase. The main objective of grinding is to increase the extent of the interface between water and coffee in order to obtain a high-quality coffee brew. However, while the coffee-grinding process is essential for the preparation of high-quality coffee, it is also a crucial factor in the deterioration of coffee quality. Grinding exposes a greater surface area of the coffee bean to oxygen, allowing for the loss of coffee volatiles and the increase in oxidative reactions. Thus, because ground coffee beans have a larger surface area exposed to the air, they deteriorate more rapidly than whole beans. One study reported that the most important factor in Arabica coffee deterioration was the specific surface area of coffee particles in contact with oxygen in the air (Baesso *et al*. 1990). This result was confirmed by Leino *et al*. (1992), who found that compounds used as ageing indicators in Arabica

coffee increased more rapidly in ground coffee than in whole beans. Changes in the volatile profile of freshly ground Arabica coffee and ground coffee 15 min postgrinding have also been found (Mayer and Grosch 2001).

Current recommendations for quality coffee preparation suggest that the coffee beans may be kept whole at room temperature for several weeks or frozen in an airtight container for several months before becoming stale (McGee 2004). McGee (2004) suggested that once the beans have been ground, the room temperature shelf life is several days while Radtke-Granzer and Piringer (1981) found that ground coffee, once opened, has a shelf life of less than 1 month at room temperature storage. While these suggestions are valuable and some research has addressed ground coffee storage under different conditions, no research has yet addressed the storage of coffee under consumer conditions and associated changes in specific sensory attributes.

The objective of this study was to determine if sensory differences could be perceived in coffee stored for different lengths of time (fresh, 1, 2 and 3 weeks) at room or freezing temperatures, and to identify the specific attribute changes over these storage periods and conditions.

MATERIALS AND METHODS

Coffee Preparation

Colombian Arabica coffee beans (French roast) were obtained from Moxie Java International (Garden City, ID). Unsalted top crackers were obtained from Safeway (Pullman, WA). The same batch of beans was used for all coffee samples. Prior to grinding, coffee beans were stored in an airtight container at room temperature. The amount of beans was measured using a Bunn Smart Funnel (Springfield, IL) that was positioned over the grinder. The coffee beans were ground using an automatic BUNN BrewWISE (Springfield, IL) commercial coffee bean grinder to fine drip brewing size as per the manufacturers' instructions. Following storage, coffee was prepared using 93.6 g of ground coffee. Samples were brewed identically using an industrial Bunn Infusion Series Digital Brewing System (Springfield, IL) and the brewing water was filtered by the Everpure E-Series Filtration System (Hanover Park, IL). To maintain a hot serving temperature, the coffee was maintained in 2.2-L single air pot brewers (Wilbur Curtis Company, Montebello, CA).

Coffee Storage

A retrospective design was used to design the storage study so that stored samples of different ages could be tested together. For room temperatures

storage, coffee was ground 3 weeks prior to the start of the study (referred to as "3 week"). The coffee grounds were packed in a 150-g mylar-gusseted bag with tin-tie closure top and stored at room temperature (22C) in a dark cupboard. Two days after, the coffee beans from the same batch were ground in the same manner and stored at freezer temperature (–23C). Storage conditions were maintained without light or product disruption. The coffee beans were ground 2 weeks (2 week) and 1 week (1 week) prior to the sensory evaluation studies following the previously mentioned procedure. On the day of the sensory panel, coffee beans from the same batch were ground; these grounds were considered the freshly ground beans (fresh).

Sensory Panels. Study 1 was defined as the triangle difference tests, and study 2 was defined as the directional paired difference tests (described later). The sensory panel was recruited from the Washington State University and the panelists were coffee consumers. The sensory panel was composed of 36 untrained panelists between the ages of 18 and 58 years (study 1). Day 1 of the triangle test was composed of 20 men and 16 women, and day 2 was composed of 18 men and 18 women. Thirty untrained panelists participated in study 2 and was composed of 17 men and 13 women (day 1) and 11 men and 19 women (day 2). The project was approved by the Washington State University Institutional Review Board and all participants signed an Informed Consent Form. For all panels, the panelists were screened for known anosmias and other conditions that may have affected their performance in this panel. A minimum amount of information on the nature of the study was provided in order to reduce potential bias. Sensory tests were conducted and data were collected and analyzed using Compusense 5-plus software (Compusense, Inc., Guelph, ON).

Coffee (30 mL) was served in 8-oz insulated beverage cups, labeled with a three-digit code and served in a random serving order. The panelists were provided with water and unsalted top crackers for cleansing the palate between samples.

In the triangle difference testing, samples included fresh, 1-, 2- and 3-week-stored samples. The triangle tests were conducted over two panel days to accommodate the retrospective design, and an incomplete balanced block design was used (Poste *et al*. 1991). Following the triangle test, a small experienced panel was assembled to determine the appropriate descriptors for differences between coffee treatments. Comments from the panelists correctly identifying the different sample during the triangle test were also taken into account in determining the appropriate attributes for the directional paired difference tests. As no differences were found between the 3-week storage (at either temperature) and the other treatments, this storage time was omitted from the directional paired difference tests.

Directional paired difference tests (Poste *et al*. 1991) for aroma, flavor, bitterness and preference were performed on coffee stored for 0, 1 and 2 weeks. The panelist was presented with three flights of two samples and asked to identify which sample had a "stronger coffee aroma," which sample had a "stronger coffee flavor," which sample was "more bitter" and which sample was "more preferred." A balanced block design was used and the panelists were asked to comment on the selected sample.

Statistical analyses for both the triangle and paired differences tests were performed as described by Roessler *et al*. (1978), and significance was calculated based on the number of correct answers per number of panelists.

RESULTS AND DISCUSSION

Table 1 shows the results of the triangle tests of coffee prepared from grounds stored at room temperature for up to 3 weeks. The panelists were able to differentiate between fresh coffee and coffee stored for 2 weeks. No differences were observed between the fresh coffee and the coffee stored for either 1 or 3 weeks. Two weeks of storage appeared to result in a difference that was not continued through to the third week of storage. There appeared to be changes that occurred following 1 week of storage, which, by 2 and 3 weeks, seemed to dissipate.

In studying the differences in frozen storage time of coffee, results showed that the panelists could differentiate between coffee prepared with grounds stored for 1 or 2 weeks (Table 2). No differences were observed between the fresh and 3-week-stored samples.

The results of paired difference tests for the coffee stored at room temperature are shown in Table 3. Coffee prepared from 1-week-stored ground

TABLE 1.
DIFFERENCE TEST RESULTS OF COFFEE PREPARED FROM GROUNDS STORED AT ROOM TEMPERATURE (22C) FOR 0 (FRESH), 1, 2 AND 3 WEEKS

	Fresh	1 week	2 week	3 week
Fresh	–	18 (9)	15 (9)	18 (9)
1 week	18 (9)	–	18 (8)*	21 (8)
2 week	15 (9)*	18 (8)	–	18 (9)
3 week	18 (9)	21 (8)	18 (9)	–

Numbers represent the number of panelists judging the comparison.
Numbers in brackets represent the number of correct panelists.
* Significant at $P < 0.05$ ($n = 30$).

TABLE 2.
DIFFERENCE TEST RESULTS OF COFFEE PREPARED FROM GROUNDS STORED AT FROZEN TEMPERATURE (–23C) FOR 0 (FRESH), 1, 2 AND 3 WEEKS

	Fresh	1 week	2 week	3 week
Fresh	–	18 (9)	15 (7)	18 (5)
1 week	18 (9)	–	18 (10)*	21 (9)
2 week	15 (7)	18 (10)*	–	18 (8)
3 week	18 (5)	21 (9)	18 (8)	–

Numbers represent the number of panelists judging the comparison.
Numbers brackets represent the number of correct panelists.
* Significant at $P < 0.05$ ($n = 30$).

TABLE 3.
RESULTS FROM THE DIRECTIONAL PAIRED DIFFERENCE TEST OF COFFEE PREPARED FROM GROUNDS STORED AT ROOM TEMPERATURE (22C) OVER 0, 1 AND 2 WEEKS

Comparison	Storage time†	Stronger aroma	Stronger flavor	More bitter	Preferred
Fresh versus	F	15	11	7	19
1 week	1	15	19	23*	11
Fresh versus	F	22*	15	10	20*
2 week	2	8	15	20*	10
1 versus	1	17	17	21*	9
2 week	2	13	13	9	21*

For each comparison, the numbers of panelists selecting coffee as having "stronger coffee aroma," "stronger coffee flavor," "more bitterness" and "preferred" are shown.
* Significant at $P < 0.05$ ($n = 30$).
† F, fresh coffee; 1, 1-week-stored coffee; 2, 2-week-stored coffee.

coffee was more bitter compared with coffee prepared from freshly ground and 2-week-stored ground coffee ($P < 0.05$).

Coffee prepared from the 2-week-stored ground coffee was more bitter than the freshly ground coffee ($P < 0.05$). However, freshly ground coffee was found to have a significantly stronger coffee aroma compared with the 2-week stored coffee. No significant differences in coffee flavor were observed between the three storage times. The panelists were found to prefer fresh coffee compared to the 2-week stored coffee, and preferred the 2-week-stored coffee over the 1-week-stored coffee.

Table 4 shows the results for the coffee stored at frozen temperature. The 2-week-stored coffee was found to have a stronger coffee aroma and more bitterness compared with the fresh coffee ($P < 0.05$). No significant differences were found in flavor or overall preference.

TABLE 4.
RESULTS FROM THE DIRECTIONAL PAIRED DIFFERENCE TEST OF COFFEE PREPARED FROM GROUNDS STORED AT FREEZER TEMPERATURE (–23C) OVER 0, 1 AND 2 WEEKS

Comparison	Storage time†	Stronger aroma	Stronger flavor	More bitter	Preferred
Fresh versus	F	15	15	18	16
1 week	1	15	15	12	14
Fresh versus	F	9	11	7	17
2 week	2	21*	19	23*	13
1 versus	1	12	16	14	16
2 week	2	18	14	16	14

For each comparison, the numbers of panelists selecting coffee as having "stronger coffee aroma," "stronger coffee flavor," "more bitterness" and "preferred" are shown.
* Significant at $P < 0.05$ ($n = 30$).
† F, fresh coffee; 1, 1-week-stored coffee; 2, 2-week-stored coffee.

As widely reported in the literature, many chemical changes occur during the storage of coffee, resulting in changes in the coffee's sensory profile. Staling of roasted Arabica coffee has been widely observed using aroma indices. In early research, a methylfuran and 2-butanone (M/B) index was developed as an indicator of staling in a roasted ground coffee solution (Reymond *et al*. 1962). Further research reported a linear correlation ($r^2 = 0.96$) between the sensory evaluation of stored ground coffee and the M/B index (Vitzthum and Werkhoff 1978). Leino *et al*. (1992) conducted a study to observe changes in various coffee blends, both ground and whole beans, during storage at room temperature up to 1 year. In the varieties of coffee studied, the compounds found to be useful indicators of ageing included 2,5-dimethylfuran and 2-methylbutanal. The ratio of acetone : butanedione was also found to increase during storage.

A greater number of attribute differences were observed over time in coffee prepared from room temperature-stored coffee compared with coffee prepared from freezer-stored coffee. In several studies, the effect of storage temperature on the shelf life of ground coffee (of same moisture content) was found to be consistent with the Arrhenius equation in that with each 10C increase in temperature, a ~50% decrease in shelf life is observed (Ernst 1979; Sivetz and Desrosier 1979). In another study, Cardelli and Labuza (2001) calculated Q10 values and the energy of activation for the deterioration of stored Arabica coffee. These researchers confirmed the results of a previous study, which reported that the shelf life deterioration of Arabica coffee was controlled by a diffusion process that displayed little temperature sensitivity (Labuza and Schmidl 1985). However, even with this low temperature sensitivity, ground coffee at freezer storage compared to that at room temperature storage would be expected to have an increased shelf life of ~70%. Thus,

because of the kinetics of deterioration, over time more differences in attributes would be expected in coffee stored at room temperature compared to that stored at frozen temperature, a result observed in the current study.

Coffee aroma varied with the storage temperature. At room temperature, fresh ground coffee was found to have a stronger coffee aroma than the 2-week sample. This result was expected as volatile compounds are lost from coffee during storage, resulting in a weaker coffee aroma over continued storage (Buffo and Cardelli-Freire 2004). This result was not observed with the frozen storage samples as the 2-week-stored coffee had a stronger coffee aroma than the fresh sample. As reported in a previous study, volatile compounds are lost almost immediately upon completion of grinding (Mayer and Grosch 2001). The frozen samples may have been placed in the freezer slightly faster than the coffee was prepared from the fresh sample, resulting in the conservation of more of the coffee volatiles responsible for aroma. The freshly ground sample may have lost more of the volatile compounds, resulting in a less intense coffee aroma.

The many volatile compounds that change during storage confer aroma or flavor properties onto the coffee. In the present study, the fresh coffee had a stronger aroma than the 2-week-stored coffee did; however, a difference was not observed at 1 week of storage. The results of the present study show a similar trend as that observed by Mayer and Grosch (2001). These researchers examined the temporal changes in the aroma profile of a ground coffee sample following grinding. Results showed that the intensity of the sweetish/caramel-like odor of the ground Colombian coffee 15 min following grinding was scored distinctly lower by a sensory panel compared with freshly ground coffee. This was attributed to the decrease in the release of Strecker aldehydes and diones. The intensity of the earthy and smoky notes also increased over storage.

In addition to aroma, bitterness was also found to differ between samples. For both storage temperatures, the general trend was observed in which the fresh sample was less bitter than the stored samples. The bitter and astringent taste associated with coffee is largely attributed to phenolic acids. During storage, these phenolic compounds may undergo oxidation, resulting in the additional generation of bitter compounds (Drewnoski 2001). Thus, stored coffee may have a higher degree of bitterness than a freshly ground sample. In addition, over storage coffee loses many of its volatile compounds, enhancing the bitterness component of the coffee (Leino *et al*. 1992).

Differences in preference for the fresh and stored coffee varied with the individual. Consumer expectations and perceptions are based on both the extrinsic and intrinsic cues of a product (Issanchou 1996). Extrinsic properties are composed of aspects related to the process of eating (physiology, anatomy; Roberts *et al*. 2003) and psychosocial and cognitive factors (Capaldi 1996).

Intrinsic cues are composed of the inherent sensory properties of a product, such as the appearance, taste and aroma. In a study relating consumer preference to the sensory attributes of instant coffee, the researchers identified four consumer groups based on consumer preference (Geel *et al*. 2005). Two groups, the "general coffee drinkers" and "not serious coffee drinkers," had little preference for specific sensory properties of coffee. However, the "pure coffee lovers" preferred the more astringent, bitter and roasted coffee while the "coffee blend lovers" preferred higher sweetness and less intense coffee flavor. In the present study, the composition of the panel probably included representatives from all of these groups. Hence, the preference differences observed may be attributed to the consumer coffee group to which the panelist identified. Inter-individual differences in flavor preferences in coffee were also found to vary based on people's preferences, modes of preparation and serving temperature (Yeretzian *et al*. 2004).

This study generated a number of interesting research questions. Future studies will involve gas chromatography (GC)-mass spectrometry and GC-olfactometry to identify the specific compounds that contribute to the differences in taste and aroma in stored ground coffee. Future studies may also involve studying the impact of commonly encountered consumer storage conditions on the resulting coffee quality.

CONCLUSION

This study showed that sensory changes occurred in ground coffee during storage at room and freezer temperatures, and these changes could be detected by a sensory panel. The specific attributes of the coffee that are most affected by storage were coffee aroma and bitterness, with fresh coffee found to have a stronger coffee aroma and stored coffee found to be more bitter. The panelists had different preferences but overall, appeared to prefer the fresh coffee compared to the stored coffees. The results indicate the importance of proper storage of ground coffee and the idea that freezer storage may be more effective at retarding some of the attribute changes during storage.

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