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Steam distillation process for flavor enhancement of milk coffee: Effects of condensation temperature on volatile compounds and flavor characteristics

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Introduction

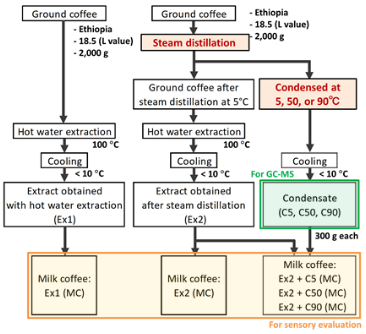
- There are numerous studies on the flavor and chemical compounds of coffee, with more than 800 aroma compounds identified [1].
- To develop milk coffee beverages with various flavor characteristics, it is important to study the extraction methods for flavor compounds from roasted and ground coffee materials.
- This study focused on the steam distillation process of coffee.

Aim of this study

- To investigate the effects of different condensation temperatures for steam distillation of roasted ground coffee on the volatile compounds in the condensates.
- To evaluate the flavor characteristics of the milk coffee samples prepared with each condensate, using the check-all-that-apply (CATA) question [2] combined with the milk coffee flavor lexicon [3] to understand consumer perception of flavor attributes.

Materials/Methods

Flow of sample preparation



Composition of milk coffee samples for sensory evaluation

Table 1 Composition of milk coffee samples for sensory evaluation

	Sample				
	Ex1 (MC)	Ex2 (MC)	Ex2 + C5 (MC)	Ex2 + C50 (MC)	Ex2 + C90 (MC)
Full fat milk[a]	70.00	70.00	70.00	70.00	70.00
Coffee extract (Ex1)	16.00	–	–	–	–
Condensate (5°C)	–	–	0.48	–	–
Condensate (50°C)	–	–	–	0.48	–
Condensate (90°C)	–	–	–	–	0.48
Coffee extract (Ex2)	–	16.00	16.00	16.00	16.00
Sugar	3.50	3.50	3.50	3.50	3.50
Water	10.50	10.50	10.02	10.02	10.02
Total	100.00	100.00	100.00	100.00	100.00

(Units: g)

GC-MS analysis

Sample vol.	1 ml	Gas chromatograph	7890B*
Extraction	35°C, 3 min	Mass spectrometer	5977B*
Fiber	SPME	Capillary column	DB-WAX UI*
Statistics	JMP 14.0.0 (SAS Institute Inc.)	Flow rate	1.2 ml/min
Oven conditions			
40°C, 2 sec → up to 120°C (4°C/min) → up to 240°C (6°C/min) → 10 min			

*Agilent Technologies

CATA question (sensory evaluation)

Panel	66 consumers (35 male and 31 female)	How to serve	White plastic cup with lid
Sample temp.	Under 10°C	Humidity	55%
Sample vol.	80 ml	Room temp.	24°C
How to drink	Using a straw	Statistics	XLSTAT (Lumivero, U.S.A.)

Table 2 Milk coffee flavor lexicon for Japanese consumers [3]

Taste (14 terms)		Aroma (35 terms)				Texture (4 terms)
Bitter	Salty	Milk	Espresso	Almond	Chocolate	Crisp
Rounded bitter	Umami	Coffee whitener	Ground coffee	Instant coffee	Bitter chocolate	Coarse
Acidic	Astringent	Cream	Flower	Honey	Caramel	Creamy
Sweet	Unclean	Fatty	Tarry	Citrus	Cacao	Rich
Lightly sweet	Refreshing sweet	Condensed milk	Carbony	Fruity	Grass	
Harsh	Mild	Artificial	Roast	Cherry	Green	
Sugar	Rich	Chemical	Smoke	Barley	Wood	
		Coffee	Burnt	Tea	Earthy	
		Coffee beans	Nutty	Soy		

Results/Discussion

Table 3 Principal component (PC) loadings obtained from PC analysis of GC-MS data for condensates.

Volatile compound		PC loading	
No.	Name (IUPAC)	PC1	PC2
1	Propanal	0.98	0.00
2	Butan-2-one	1.00	0.05
3	2-Methylbutanal	0.99	-0.13
4	3-Methylbutanal	0.99	-0.09
5	2,5-Dimethylfuran	0.95	-0.28
6	Hexan-3-one	1.00	-0.07
7	Pentan-2,3-dione	0.97	0.22
8	Ethyl 3-methylbutanoate	0.97	-0.17
9	Dimethyldisulfide	0.98	-0.20
10	2-Vinylfuran	0.96	-0.26
11	Hexanal	0.99	-0.03
12	2-Methylthiophene	0.94	-0.29
13	2-Methylbut-2-enal	0.99	-0.04
14	1-Methyl-1H-pyrrole	0.99	0.00
15	α-Terpinene	0.95	-0.31
16	1-Ethylpyrrole	0.98	-0.14
17	Pyridine	0.89	-0.29
18	p-Mentha-1,8-diene	0.93	-0.36
19	Trimethyloxazole	0.98	0.06
20	Pyrazine	0.90	0.02
21	2-Pentylfuran	0.93	-0.32
22	2-(Methoxymethyl) furan	0.97	0.20
23	β-Ocimene	0.91	-0.36
24	Methylpyrazine	-0.85	0.37
25	Terpinolene	0.94	-0.32
26	2,5-Dimethylpyrazine	0.67	0.67
27	Ethylpyrazine	0.75	0.53
28	Dimethyltrisulfide	0.99	-0.07
29	2-Ethyl-6-methylpyrazine	0.40	0.84
30	2,6-Diethylpyrazine	0.82	0.22
31	Acetic acid	-0.91	0.12
32	2-Furaldehyde	-0.86	0.28
33	Furfuryl methyl sulfide	1.00	0.07
34	2-Methyl-6-vinylpyrazine	0.83	-0.29
35	2-Furyl methyl ketone	0.91	-0.05
36	Benzaldehyde	0.97	0.14
37	Furfuryl acetate	0.82	0.22
38	3,7-Dimethylocta-1,6-dien-3-ol	0.94	0.28
39	5-Methyl-2-furaldehyde	-0.78	0.49
40	2-Furfurylfuran	0.98	0.16
41	1-Methylpyrrole-2-carbaldehyde	0.74	0.50
42	4,7-Dimethylbenzofuran	0.89	0.41
43	Methyl 2-hydroxybenzoate	0.95	0.28
44	1-Furfurylpyrrole	0.88	0.44
45	Difurfuryl ether	0.66	0.54
46	4-Ethylphenol	-0.67	-0.55
	Eigenvalue	37.9	4.6
	Cumulative contribution ratio (%)	82.2	92.2

As 39 out of 46 volatile compounds showed the PC1 factor loadings (red in the left column) that were larger than 0.8, the positive direction of the PC1 axis in Figure 2 was considered to present overall high concentration of aroma compounds, and negative direction was considered to represent the opposite.

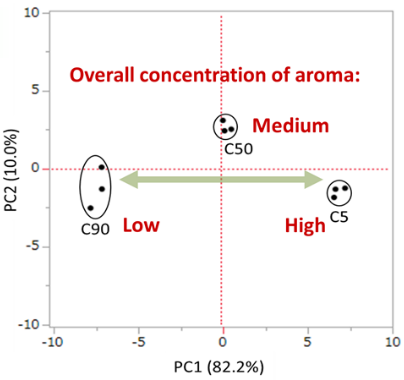


Figure 2 Two-dimensional scatter plot of PC scores by PC analysis of GC-MS data.

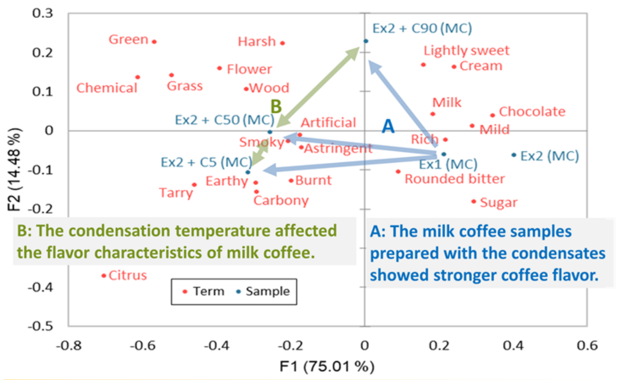


Figure 3 Correspondence analysis of frequency of use of terms in check-all-that-apply (CATA) question for milk coffee samples. Of the 53 terms, the terms that showed a significant difference in Cochran's Q test between the samples are shown ($p < 0.05$).

Conclusion/Perspectives [4]

[GC–MS]

- PC analysis results indicated that each condensate was characterized by their overall concentration of aroma.

[Sensory Evaluation]

- The milk coffee samples prepared with the condensates showed stronger coffee flavor than those prepared without the condensates.
- Changing the condensation temperature for steam distillation was considered to be effective for providing various flavor characteristics for milk coffee.

[Practical Application]

- Application of steam distillation for coffee extraction process is considered to be effective to produce milk coffee that have more broader range of flavor characteristics from the same starting coffee material.
- Based on the results of the study, Morinaga Milk Industry Co., Ltd. has installed a steam distillation system for coffee in its own beverage plant and utilizes it for the production of ready-to-drink milk coffee.

References:

[1] Flament, I., & Bessière-Thomas, Y. 2002, *Coffee Flavor Chemistry*, pp. 53-74, [2] Hatakeyama *et al.* 2023, *Food Science and Technology Research*, 29(3), 197-209,
[3] Meyners, M., & Castura, J. C. 2014, Check-all-that-apply questions, pp. 284-319, [4] Hatakeyama *et al.* 2024, *Journal of Food Science*, 89, 3330-3346