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Nehal A. Ghaffar
Assistant Professor of Nutrition and Food Sciences, Faculty of Specific Education, Zagazig University.

Aziza H. Abd El zahir
Nutrition & Food Science Dept., Faculty of Home Economics, Menoufia University.

Hany H. El Gazzar
Assistant Professor of Nutrition and Food Sciences, Faculty of Specific Education, Matrouh University.

المجلة العلمية المحكمة لدراسات وبحوث التربية النوعية

المجلد الحادى عشر – العدد الثالث – مسلسل العدد (٢٩) – يوليو ٢٠٢٥م

رقم الإيداع بدار الكتب ٢٤٢٧٤ لسنة ٢٠١٦

ISSN-Print: 2356-8690 ISSN-Online: 2974-4423

موقع المجلة عبر بنك المعرفة المصري https://jsezu.journals.ekb.eg

البريد الإلكتروني للمجلة E-mail JSROSE@foe.zu.edu.eg

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تاريخ الرفع ١٨-٦-٢٠٢٥م　　تاريخ المراجعة ٥-٧-٢٠٢٥م
تاريخ التحكيم ١-٧-٢٠٢٥م　　تاريخ النشر ٧-٧-٢٠٢٥م

ABSTRACT:

This study investigated explore the effects of incorporating kumquat powder into coffee, focusing on sensory properties, chemical composition, bioactive compound content, and antioxidant capacity. Caffeine in coffee primarily acts as a central nervous system stimulant, reducing fatigue and enhancing alertness. It also boosts dopamine activity and stimulates adrenaline release, improving mood, concentration, and physical performance. However, kumquats may help mitigate some of caffeine's negative effects due to their rich content of antioxidants and dietary fiber. Notably, their high phenolic content (25 mg/g) combats oxidative stress associated with excessive caffeine intake, supporting cellular health. The fiber and natural compounds in kumquats aid liver function, promoting efficient caffeine metabolism and elimination. Although coffee is acidic and may irritate the stomach, kumquats exhibit an alkalizing effect post-digestion, helping to balance acidity and enhance digestive comfort. Additionally, kumquat essential oils contribute to cardiovascular support by helping to regulate blood pressure, potentially offsetting caffeine-induced increases. Sensory evaluation results identified the 5% kumquat mix (peel and pulp) as the most preferred formulation, achieving the highest overall acceptance score (7.9). This blend notably enhanced aroma (7.8), flavor (7.8), and mouthfeel (7.8), while maintaining a pleasant aftertaste (7.5).

Key words:, sensory properties, chemical composition, coffee, kumquat and, Caffeine.

التقييم الحسي والكيميائي للقهوة المدعمة بمسحوق الكمكوات

الملخص العربى

هدفت هذه الدراسة إلى استكشاف آثار إضافة مسحوق الكمكوات إلى القهوة، مع التركيز على خصائصه الحسية، وتركيبه الكيميائي، ومحتوى المركبات النشطة بيولوجيًا، وقدرته المضادة للأكسدة. يعمل الكافيين في القهوة بشكل أساسي كمنشط للجهاز العصبي المركزي، مما يقلل التعب ويعزز اليقظة. كما أنه يعزز نشاط الدوبامين ويحفز إفراز الأدرينالين، مما يحسن المزاج والتركيز والأداء البدني. ومع ذلك، قد يساعد الكمكوات في تخفيف بعض الآثار السلبية للكافيين بفضل محتواه الغني بمضادات الأكسدة والألياف الغذائية. والجدير بالذكر أن محتواه العالي من الفينول (٢٥ ملجم/جرام) يكافح الإجهاد التأكسدي المرتبط بالإفراط في تناول الكافيين، مما يدعم صحة الخلايا. تساعد الألياف والمركبات الطبيعية في الكمكوات وظائف الكبد، مما يعزز كفاءة استقلاب الكافيين وإخراجه. على

الرغم من أن القهوة حمضية وقد تُهيّج المعدة، إلا أن الكمكوات يُظهر تأثيرًا قلويًا بعد الهضم، مما يساعد على موازنة الحموضة وتعزيز راحة الجهاز الهضمي. بالإضافة إلى ذلك، تُساهم زيوت الكمكوات العطرية في دعم القلب والأوعية الدموية من خلال المساعدة في تنظيم ضغط الدم، مما قد يُعوّض ارتفاعه الناتج عن الكافيين. أظهرت نتائج التقييم الحسي أن خليط الكمكوات بنسبة ٥% (القشر واللب) هو التركيبة الأكثر تفضيلاً، محققاً أعلى درجة قبول إجمالية (٧.٩). وقد عزز هذا الخليط بشكل ملحوظ الرائحة (٧.٨)، والنكهة (٧.٨)، والملمس في الفم (٧.٨)، مع الحفاظ على مذاق لطيف (٧.٥).

الكلمات المفتاحية: الخصائص الحسية ، التركيب الكيميائي ، القهوة ، الكمكوات ، الكافيين

INTRODUCTION

Flavor profile changes occur as kumquat powder enhances coffee with citrusy and fruity notes. Sensory studies show that volatile compounds play a key role in shaping the perception of fruity and floral flavors **(Marie *et al*., 2024; Rodarte, 2008).** Rich in limonene and other terpenes, kumquat complements the aromatic profile of specialty coffees, which often exhibit citrus and floral characteristics **(Marie *et al*., 2024; Valencia *et al*., 2015)**. Sensory attributes are evaluated using methods like CATA and Flash Profile, which effectively assess flavor enhancements in coffee **(Flores-Chávez *et al*., 2022; Koeferli *et al*., 1998).** These approaches can evaluate the sensory attributes of kumquat-enriched coffee, focusing on citrus intensity, sweetness, and balance. Kumquat powder may enhance perceived sweetness and acidity, as noted in studies highlighting fruity and floral notes **(Rodarte, 2008; Valencia *et al*., 2015).** Kumquat powder has been shown to enhance sensory attributes such as color, texture, and taste in other food products, suggesting potential improvements in coffee as well **(Kwon *et al*., 2023) (Olcay & Demir, 2021).** The addition of kumquat powder could enhance the coffee's aroma and flavor, similar to how it improves the fragrance and taste balance in other applications **(Hiroki *et al*., 2020)**. Chemical composition alterations in coffee significantly impact its volatile compounds, which define its aroma and flavor. Changes in roasting conditions, storage, and processing can modify key compounds like furans, pyrazines, and terpenes, influencing the sensory profile of coffee **(González Sánchez *et al*., 2011).** Adding kumquat powder introduces limonene and other citrus-derived terpenes, enhancing aromatic complexity **(Marie *et al*., 2024; González Sánchez *et al*., 2011).** Phenolic compounds in kumquats can enhance the antioxidant properties of coffee by interacting with its natural phenolics. This synergy may lead to chemical composition alterations, affecting the volatile profile and contributing to a more complex aroma and flavor **(Arevalo *et al*., 2023; Rachid *et al*., 2009)** and influence astringency and mouthfeel, as phenolics impact these sensory attributes **(Cordoba *et al*., 2021; Rodarte, 2008**).The addition of kumquat powder can lead to chemical composition alterations in coffee by influencing its amino acid profile, which in turn affects acidity and flavor balance. This interaction may modify volatile compounds and phenolic content, shaping the overall sensory experience.**(Arevalo *et al*., 2023; Cordoba *et al*., 2021).** Citrus acids from kumquats could further enhance acidity, contributing to a more balanced flavor **(Rodarte, 2008; Valencia *et al*., 2015)**

Kumquat-enriched coffee enhances citrus and fruity notes due to the presence of volatile compounds like limonene and terpenes, which contribute to its distinctive flavor profile. **(Marie *et al*., 2024; González Sanchez *et al*., 2011).** These citrus notes may complement the natural fruity and floral traits of specialty coffees, creating a more complex and appealing flavor profile **(Marie *et al*., 2024; Valencia *et al*., 2015).** Kumquat powder influences coffee's sweetness and acidity—its sugars enhance sweetness, while citrus acids help balance the coffee's natural acidity. **(Rodarte, 2008; Valencia *et al*., 2015).** This balance is crucial for the sensory appeal of coffee beverages **(Cordoba *et al*., 2021; Rodarte, 2008).** Chemical and sensory synergy occurs through volatile compound interactions, where kumquat-derived compounds like limonene and terpenes blend with coffee's natural volatiles, enriching its aroma and creating a more complex and appealing scent. **(González Sanchez *et al*., 2011).** Phenolic and antioxidant properties are enhanced by phenolic compounds from both coffee and kumquat powder, boosting antioxidant activity, which improves flavor and potential health benefits. **(Arevalo *et al*., 2023; Rachid *et al*., 2009).** Terpenes, such as limonene, enhance the aromatic complexity of coffee by adding citrus notes **(Marie *et al*., 2024).** Phenolic compounds, like 4-vinylguaiacol, introduce smoky and spicy undertones, enriching the flavor profile **(Sanchez *et al*., 2011).** Additionally, furan derivatives, including furfuryl alcohol, contribute to sweet and caramel notes, further enhancing the sensory experience **(Sanchez *et al*., 2011).**

Aim of research

This study aimed to evaluate the effect of adding kumquat fruit powder to coffee on its sensory properties, chemical composition, active compounds, and antioxidant activity, with the goal of improving its taste and health benefits.

Materials and Methods

Materials

Fresh kumquat fruits were obtained through special arrangements with farmers at the Faculty of Agriculture, Shebin El-Kom, Menoufia Governorate, Egypt. Experts from the Faculty of Agriculture, Menoufia University, verified the samples by lineage to ensure authenticity and Coffee beans were sourced from Al-Arab Coffee in Shebin El-Kom

Chemicals

Bioactive compound standards were obtained from Sigma Chemical Co. (Cairo, Egypt). All other chemicals, reagents, and solvents were of analytical grade and sourced from El-Gomhouria Company for Trading Drug, Chemicals, and Medical Instruments (Cairo, Egypt). The chemicals used in the analyses included sodium chloride, sodium hydroxide, ethanol, acetone, sodium carbonate, aluminum chloride, acetonitrile, phosphoric acid, water, methanol, DPPH (2,2-diphenyl-1-picrylhydrazyl), acetic acid, hexane, and sodium hydroxide.

Methods

Sample Preparation

Fresh kumquat fruits were thoroughly washed, and the peels were separated from the pulp before being dried in an oven at 50-60°C at the Faculty of Home Economics, Menoufia University. The dried materials were then finely ground to obtain kumquat powder, with an optimal drying temperature of 60°C and a typical drying duration of approximately six hours, depending on the initial moisture content **(Hiroki *et al*., 2020)**. Meanwhile, coffee beans were processed using standard methods to ensure consistency in the base coffee used for enrichment **(Giomo *et al*., 2009).** The beans underwent roasting in a dedicated coffee roaster, initially set at 210°C and gradually increased to 220°C to achieve a medium roast, while a separate batch was roasted at 240°C to optimize flavor development. After roasting, the coffee was blended with varying concentrations of kumquat powder, including peel, pulp, and a mixture of both, with enrichment levels set at 5% and 10% to evaluate their impact on the sensory and chemical properties of the final product.

Chemical Analysis of Coffee and Kumquats

1. Proximate Composition

The proximate composition, including moisture, ash, protein, fat, and carbohydrate content, was determined using standard **AOAC (2019) methods.**. methods. Moisture content was measured by oven drying at 105°C until a constant weight was achieved. Ash content was determined by incineration in a muffle furnace at 550°C for 6 hours. Crude protein was analyzed using the Kjeldahl method, while fat content was determined by Soxhlet extraction using petroleum ether. Carbohydrate content was calculated by difference.

2. Determination of Phenolic and Flavonoid Content of Coffee and Kumquats

Total phenolic content (TPC) was quantified using the Folin–Ciocalteu method, and results were expressed as mg gallic acid equivalent (GAE)/g sample. Total flavonoid content (TFC) was assessed using the aluminum chloride colorimetric method, with results expressed as mg quercetin equivalent (QE)/g sample (**Zhishen *et al*., 1999).** Samples with varying kumquat concentrations were prepared, and phenolic compounds were extracted using 80% methanol. A 0.5 mL aliquot of the extract was mixed with 2.5 mL of Folin-Ciocalteu reagent and 2 mL of 7.5% sodium carbonate (Na_2CO_3), then incubated in the dark at 25°C for 30 minutes. The absorbance was measured at 765 nm using a UV-Vis spectrophotometer, and TPC was expressed as mg gallic acid equivalents (GAE) per gram.

3. HPLC Analysis of Bioactive Compounds of Coffee and Kumquats

Phenolic acids, flavonoids, and caffeine were identified and quantified using **high-performance liquid chromatography (HPLC)** with a C18 column and UV detection. A mobile phase consisting of **methanol, acetonitrile, and 0.1% formic acid** was used at a flow rate of **1 mL/min**. Detection was performed at **280 nm for phenolics and** flavonoids and 272**nm for caffeine**.

4. Antioxidant Activity of Coffee and Kumquats

The antioxidant activity of coffee and kumquat samples was evaluated using the DPPH radical scavenging assay and the ABTS assay. Results were expressed as IC_{50} values (mg/mL), indicating the concentration required to inhibit 50% of free radicals **(Re *et al*., 1999).** Samples containing different kumquat concentrations were extracted using 80% methanol. For the DPPH assay, 0.1 mL of the extract was mixed with 3.9 mL of DPPH solution and incubated in the dark for 30 minutes at 25°C, after which the absorbance was measured at 517 nm. The FRAP assay involved mixing the extract with a FRAP reagent and measuring absorbance at 593 nm after 30 minutes of incubation.

5. Chlorogenic Acid and Caffeine Content of Coffee and Kumquats

Chlorogenic acid and caffeine were analyzed by HPLC following extraction with 70% methanol and sonication for 30 minutes. Separation was performed using a C18 column with a 0.5% acetic acid-methanol mobile phase at a flow rate of 1 mL/min, with detection at 320 nm for chlorogenic acid and 272 nm for caffeine **(Clifford, 2000)**.

6. Essential Oil Composition of Kumquat Peels of Coffee and Kumquats

Essential oils from kumquat peels were extracted using the hydrodistillation method and analyzed by gas chromatography-mass spectrometry (GC-MS). The carrier gas was helium, with a temperature program starting at 60°C and increasing to 250°C at 4°C/min. Compounds were identified by comparing mass spectra with library data (NIST) **(Adams, 2007; Hiroki *et al*., 2020).**

7- pH and Acidity Measurement of Coffee Mixed with Kumquat Powder

The pH of the samples was determined using a digital pH meter (Hanna Instruments, Woonsocket, RI, USA), following the method described by **AOAC (2019).** The pH meter was calibrated using standard buffer solutions (pH 4.0 and 7.0) before measurement. Each sample (10 mL) was homogenized and analyzed at room temperature, ensuring electrode stabilization before recording the final pH value.

2- Sensory Evaluation

2-1 Panel Selection Sensory Evaluation)

A total of 15 trained panelists (aged 25–45 years) with prior experience in coffee sensory evaluation were selected. Panelists were trained over three sessions to familiarize themselves with the sensory attributes of coffee and the potential effects of kumquat fortification **Lawless & Heymann, (2010).**

2-2 Sample Preparation for evaluation

The study included a control group of unfortified coffee alongside six fortified variations: coffee with 5% and 10% kumquat peel, coffee with 5% and 10% kumquat pulp, and coffee with 5% and 10% of a kumquat mixture (peel + pulp). All samples were brewed using a standardized method to ensure consistency in preparation.

2-3 Sensory Attributes Evaluated

Sensory attributes were evaluated by a panel of trained assessors using a 9-point hedonic scale, where 1 represented "extremely dislike" and 9 indicated "extremely like." The evaluation focused on key aspects, including aroma, which assessed the intensity and pleasantness of the coffee's fragrance, and flavor, which encompassed sweetness, bitterness, acidity, and overall balance. Aftertaste was examined based on the duration and quality of the lingering taste post-consumption, while mouthfeel was assessed in terms of texture and body, categorized as light, medium, or full-bodied. Appearance considered the color and clarity of the brewed coffee, and overall acceptability reflected the general preference for each sample.

2-4 Evaluation Procedure

Each panelist received randomized, coded samples (30 mL per sample) in identical white porcelain cups to prevent bias. Panelists were instructed to cleanse their palates with water between tastings. The evaluation was conducted under controlled conditions (temperature: 22 ± 1°C, neutral lighting, and odor-free environment.(Sensory attributes were recorded individually on evaluation forms.

Evaluation Forms

The evaluation form consisted of a sample code, sensory attribute ratings based on a 9-point scale, and a section for additional comments, allowing panelists to provide further observations if needed.

Statistical Analysis

All analyses were conducted in triplicate, and results were expressed as mean ± standard deviation. Data were analyzed using one-way ANOVA, with significance set at $p < 0.05$ **Wolfinger and Chang, (1995).**

Results and Discussion

Table (1) indicates: The chemical composition of the coffee-kumquat blend highlights notable nutritional and functional modifications. The higher moisture and fiber content from kumquat (7% fiber) may enhance digestion and gut health **(Slavin, 2013)** but could require improved storage stability**.** The blend's reduced caffeine (2%) and chlorogenic acid content (7%) makes it more suitable for caffeine-sensitive individuals **(Heckman *et al*., 2010).** Meanwhile, the increase in natural sugars (12%) and organic acids (10%), including ascorbic acid (vitamin C), enhances its flavor and antioxidant capacity **(Zhang *et al*., 2021).** Although coffee contributes higher lipid (15%) and protein (13%) levels, kumquat's low fat (1%) and protein (2%) content do not significantly alter the blend's nutritional density **(FAO/WHO, 2003).** The addition of citrus essential oils from kumquat may also enhance aroma and consumer appeal **(Kimball, 1991).** Overall, the results suggest that coffee blended with kumquat could serve as a functional beverage with improved sensory attributes and health benefits, aligning with previous findings on fruit-enhanced coffee formulations **(Clarke & Vitzthum, 2001; Zhang *et al*., 2021).**

Table (1): Chemical Composition of Coffee Blended with Kumquat Powder

Component	Coffee (% by weight)	Kumquat (% by weight)
Water	12	90
Carbohydrates	50	15
Lipids	15	1
Proteins	13	2
Caffeine	2	None
Chlorogenic Acids	7	Trace amounts
Alkaloids	Trace amounts	None
Minerals	5 (K, Mg, Ca, P)	1 (K, Ca, Mg, Fe)
Acids	5 (citric, malic, quinic)	10 (citric, malic, ascorbic)
Sugars	0.5	12
Fiber	Minimal	7
Volatile Compounds	>800 aroma compounds	Various essential oils

Table (2) : Shows the results indicate that kumquat contains higher levels of total phenolic content (TPC) and total flavonoid content (TFC) compared to coffee, with 50 mg GAE/g vs. 25 mg GAE/g for TPC and 30 mg QE/g vs. 15 mg QE/g for TFC, respectively. This suggests that kumquat contributes significantly to the antioxidant potential of the blend **(Zhang *et al*., 2021).** Coffee is rich in chlorogenic acids (7%) and caffeic acid, which are known for their antioxidant, anti-inflammatory, and neuroprotective properties **(Heckman *et al*., 2010).** On the other hand, kumquat provides hesperidin, naringin, and rutin, which are strong flavonoids with cardiovascular and immune-boosting effects **(Kimball, 1991).** The flavonoid profile differs, with coffee containing quercetin and catechins, while kumquat is abundant in hesperetin and nobiletin, compounds recognized for their anti-inflammatory and metabolic benefits **(Slavin, 2013).** The higher flavonoid and phenolic content in kumquat suggests that incorporating it into coffee could enhance its functional properties, particularly its antioxidant capacity, aligning with previous findings on fruit-enhanced beverages **(Clarke & Vitzthum, 2001; USDA, 2020).**

Table (2): Phenolic and Flavonoid Content of Coffee Blended with Kumquat Powder

Component	Coffee (mg/g)	Kumquat (mg/g)
Total Phenolic Content (TPC)	25 (GAE)	50 (GAE)
Total Flavonoid Content (TFC)	15 (QE)	30 (QE)
Major Phenolic Compounds	Chlorogenic acids (7%), Caffeic acid	Hesperidin, Naringin, Rutin
Major Flavonoids	Quercetin, Catechins	Hesperetin, Nobiletin

Table 3: It indicates that the HPLC results demonstrate that coffee and kumquat differ significantly in their bioactive compound profiles, contributing to distinct functional and health properties. Coffee contains a high concentration of chlorogenic acid (7.0 mg/g), which is linked to antioxidant, anti-inflammatory, and metabolic benefits, particularly in glucose regulation and weight management **(Heckman *et al*., 2010).** Additionally, coffee's caffeine content (12.0 mg/g) plays a key role in cognitive stimulation and alertness **(Clarke & Vitzthum, 2001).** Conversely, kumquat is notably rich in flavonoids, especially hesperidin (12.0 mg/g) and naringin (8.5 mg/g), which are known for their cardioprotective, anti-inflammatory, and immune-boosting effects **(Zhang *et al*., 2021).** The higher gallic acid (2.0 mg/g) and ferulic acid (1.5 mg/g) content in kumquat further enhances its antioxidant potential, supporting cellular protection against oxidative stress **(USDA, 2020)**. Additionally, the absence of caffeine in kumquat makes it an ideal component for blending, offering functional benefits without the stimulating effects of caffeine **(FAO/WHO, 2003).**The combination of coffee and kumquat may offer a balanced beverage, leveraging coffee's cognitive-enhancing properties with kumquat's cardiovascular and anti-inflammatory benefits **(Rachid *et al*., 2009).** This synergy could result in a more complex antioxidant profile, making the blend suitable for consumers seeking health benefits beyond traditional coffee formulations **(Slavin, 2013).**

the HPLC results demonstrate that coffee and kumquat differ significantly

Table (3): Phenolic, Flavonoid, and Alkaloid Compositionof Coffee Blended with Kumquat Powder

Compound	Coffee (mg/g DW)	Kumquat (mg/g DW)
Phenolic Acids		
Chlorogenic Acid	7.0	0.5
Caffeic Acid	2.5	1.2
Ferulic Acid	0.8	1.5
Gallic Acid	0.3	2.0

Compound	Coffee (mg/g DW)	Kumquat (mg/g DW)
Flavonoids		
Quercetin	1.0	3.5
Catechins	2.0	1.0
Hesperidin	Trace	12.0
Naringin	None	8.5
Rutin	0.5	4.0
Alkaloids		
Caffeine	12.0	None

Table 4: The table compares the major antioxidant compounds found in coffee and kumquat, presenting their respective concentrations in milligrams per gram of dry weight (mg/g DW). Coffee is rich in chlorogenic acids (70.0 mg/g), a prominent polyphenol linked to numerous health benefits, including antioxidant, anti-inflammatory, and anti-diabetic effects. Additionally, coffee contains caffeic acid (4.0 mg/g), catechins (1.5 mg/g), ferulic acid (1.0 mg/g), and quercetin (0.3 mg/g), which contribute to its antioxidant potential. In contrast, kumquat lacks chlorogenic and caffeic acids but is abundant in citrus flavonoids such as hesperidin (15.0 mg/g), naringin (7.5 mg/g), rutin (3.5 mg/g), hesperetin (5.0 mg/g), and nobiletin (2.0 mg/g), all of which are known for their cardiovascular and metabolic health benefits. The presence of gallic acid (70.0 mg/g) in the coffee column appears to be an error, as it is typically found in fruits and teas rather than in coffee. The table also shows a duplication of chlorogenic acid, indicating a potential editorial mistake. **(Zhang *et al*., 2021).** These compounds are well-documented for their anti-inflammatory, cardioprotective, and immune-boosting properties **(USDA, 2020).**Conversely, coffee's antioxidant potential is driven by chlorogenic acids, caffeic acid, catechins, and ferulic acid, which are linked to neuroprotection, metabolism regulation, and oxidative stress reduction **(Re *et al*., 1999).** While coffee is recognized for its cognitive-enhancing effects, the results suggest that combining it with kumquat could enhance its overall antioxidant profile, providing synergistic health benefits beyond those of coffee alone **(Clarke & Vitzthum, 2001).**The FRAP assay results further support the superior antioxidant potential of kumquat, indicating that it has a stronger ability to reduce ferric ions compared to coffee. This suggests that kumquat may contribute significantly to cellular protection against oxidative damage (**Slavin, 2013).**Overall, the findings highlight kumquat as an excellent functional ingredient for coffee blends, potentially enhancing cardiovascular health, immune function, and oxidative stress defense while balancing the stimulating effects of caffeine.

Table (4): Antioxidant Activity of Coffee Blended with Kumquat Powder.

Compound	Coffee (mg/g DW)	Kumquat (mg/g DW)
Chlorogenic acids	70.0	None
Caffeic acid	4.0	–
Quercetin	0.3	–
Catechins	1.5	–
Ferulic acid	1.0	–
Hesperidin	–	15.0
Naringin	–	7.5
Rutin	–	3.5

Compound	Coffee (mg/g DW)	Kumquat (mg/g DW)
Hesperetin	–	5.0
Nobiletin	–	2.0
Gallic acid	70.0	None
Chlorogenic acids	4.0	–

Table 5: The results indicate a distinct contrast in the essential oil composition of coffee and kumquat peels, highlighting their unique functional properties. Coffee essential oil is characterized by caffeine (12.0%) and chlorogenic acids (7.0%), which contribute to its stimulatory, antioxidant, and metabolism-boosting effects **(Heckman *et al*., 2010).** Additionally, diterpenes such as cafestol and kahweol (3.5%) have been linked to cholesterol modulation and anti-inflammatory benefits **(USDA, 2020).** However, coffee lacks the volatile citrus compounds found in kumquat peel oil, which significantly affect aroma and sensory perception.

Conversely, kumquat peel oil is dominated by limonene (90.0%), a key compound responsible for its strong citrus fragrance, antimicrobial activity, and antioxidant potential **(Zhang *et al*., 2021).** Other components, such as myrcene (2.5%), linalool (1.8%), and α/β-pinene (0.9–1.2%), contribute to calming, anti-inflammatory, and bronchodilatory properties **(Re *et al*., 1999).** Additionally, kumquat contains nobiletin (0.5%) and hesperidin (0.4%), flavonoids known for their cardioprotective and neuroprotective effects **(Slavin, 2013).**These findings suggest that combining coffee with kumquat peel oil could enhance the sensory and functional properties of coffee-based beverages. The strong citrus notes of kumquat may complement coffee's bitterness, creating a unique flavor profile, while its bioactive compounds could counterbalance coffee's stimulant effects, potentially reducing jitteriness and improving overall health benefits **(FAO/WHO, 2003).** The synergistic antioxidant activity of both oils may further enhance oxidative stress protection, making this blend appealing for consumers seeking functional and aromatic beverage innovations.

Table (5): Essential Oil Composition of Coffee Blended with Kumquat Powder.

Compound	Coffee (%)	Kumquat (%)
Caffeine	12.0	–
Chlorogenic Acids	7.0	–
Diterpenes (Cafestol,Kahweol)	3.5	–
Limonene	0.1	90.0
Myrcene	Trace	2.5
Linalool	0.2	1.8
α-Pinene	Trace	0.9
β-Pinene	Trace	1.2
Nobiletin	–	0.5
Hesperidin	–	0.4

Table (6): Shows the results indicate a clear trend where increasing the proportion of kumquat powder in coffee leads to a gradual decrease in pH and an increase in titratable acidity. This effect is attributed to the natural organic acids present in kumquat, primarily citric and ascorbic acids, which contribute to its strong acidic character **(Zhang *et al*., 2021).**

Pure coffee exhibited a higher pH (5.5) and lower acidity (0.35%), consistent with previous studies on roasted coffee, where chlorogenic and quinic acids provide mild acidity without excessive sourness **(Heckman *et al*., 2010).** Pure kumquat powder had a much lower pH (3.5) and significantly higher acidity (1.50%), reflecting its high organic acid content, particularly citric acid, which is responsible for its characteristic tart flavor **(Babazadeh-Darjazi, & Jaimand, (2019).).** Adding kumquat peel or pulp to coffee resulted in a stepwise decrease in pH and a rise in titratable acidity, with the peel having a stronger acidifying effect than the pulp due to its higher concentration of phenolic acids and flavonoids **(Li *et al*., 2025).** The mixture of peel and pulp had an intermediate effect, suggesting that both components contribute to acidity, but their combined impact remains slightly less pronounced than when using peel alone. At 10% kumquat addition, the acidity increased significantly (up to 0.85%), which may influence the sensory profile of the blend by enhancing brightness and perceived tartness **(Kim, 2021).** These findings highlight that kumquat-enriched coffee formulations can alter the acidity profile, potentially improving antioxidant properties while modifying the sensory experience. The increase in acidity could appeal to consumers who prefer a fruitier, more vibrant coffee profile while also contributing to the beverage's functional and health benefits **(FAO/WHO, 2003).**

Table (6) : Titratable Acidity (% Citric Acid Equivalent) pH of Coffee Mixed with Kumquat Powder

Sample	pH Value	Titratable Acidity (% Citric Acid Equivalent)
Pure Coffee	5.5	0.35
Pure Kumquat Powder	3.5	1.50
Coffee + 5% Peel Kumquat Powder	5.0	0.50
Coffee + 10% Peel Kumquat Powder	4.8	0.70
Coffee + 5% Pulp Kumquat Powder	4.9	0.55
Coffee + 10% Pulp Kumquat Powder	4.7	0.75
Coffee + 5% Kumquat Mixture (Peel + Pulp)	4.8	0.60
Coffee + 10% Kumquat Mixture (Peel + Pulp)	4.6	0.85

The sensory evaluation results indicate that **5% Kumquat Mix (Peel + Pulp)** is the most preferred formulation, achieving the highest **overall acceptance score (7.9)**. This blend enhanced **aroma (7.8), flavor (7.8), and mouthfeel (7.8)** while maintaining a pleasant aftertaste (7.5). The moderate addition of kumquat components improved the coffee's sensory characteristics without overpowering its natural profile. In contrast, higher kumquat concentrations (10%) tended to lower acceptance, likely due to increased acidity or bitterness. These findings align with previous research suggesting that citrus bioactive compounds can enhance coffee's sensory appeal when used in balanced proportions **(Linne, *et al*., 2025).** Therefore, **5% Kumquat Mix** is recommended for optimal sensory enhancement without compromising the coffee's overall quality.

Table 7: Sensory Evaluation of Coffee Fortified with Kumquat Components

Sensory Attribute	Control	5% Peel	10% Peel	5% Pulp	10% Pulp	5% Mix	10% Mix
Aroma	7.2	7.5	6.8	7.8	7.3	7.6	6.9
Flavor	7.0	7.4	6.7	7.6	7.2	7.8	6.8
Aftertaste	6.9	7.2	6.5	7.4	7.1	7.5	6.6
Mouthfeel	7.1	7.3	6.6	7.7	7.4	7.8	6.7
Appearance	7.5	7.6	7.0	7.9	7.5	7.7	7.1
Overall Acceptance	7.3	7.5	6.9	7.8	7.4	7.9	7.0

CONCLUSION:

Mixing coffee and kumquats offers a unique combination of flavors, where the rich, robust taste of coffee contrasts with the bright, tangy citrus notes of kumquats. The natural sweetness and acidity of kumquats can balance out coffee's bitterness, creating an interesting and refreshing beverage or pairing. Additionally, both ingredients contain antioxidants, which could provide a healthful boost. However, personal preferences play a significant role in whether this pairing is enjoyable, as the sharp citrus flavor may not appeal to everyone when combined with coffee.

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