Effects of *Chrysanthemum zawadskii* and *Momordica charantia* on the quality and lipid oxidation of Korean native black goat extract

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Summary

Korean native black goat is recognised for its high nutritional value, yet faces challenges like lipid oxidation. Consequently, this study investigated the effects of plants with antioxidant properties to enhance storability and quality. The plants used in this study were *Chrysanthemum zawadskii* (CZ) and *Momordica charantia* (MC), which are prevalent in Asia. The total flavonoid content and total phenolic content of CZ and MC were measured and found to be higher in CZ extract, with 28.74 g·kg^{-1} (expressed as gallic acid) and 509.86 g·kg^{-1} (expressed as naringin). The black goat extract was prepared with 10 g·kg^{-1} CZ (CZ1), 10 g·kg^{-1} MC (MC1), and 10 g·kg^{-1} CZ + 10 g·kg^{-1} MC (CZ1MC1) and a control without either CZ or MC (CON). In terms of quality, the inclusion of CZ and MC reduced moisture levels and enhanced protein content; additionally, salinity and sugar content were approximately 1–2 % higher in CZ1MC1. The extracts containing CZ and MC exhibited antioxidant activities, with all experimental groups showing significantly lower thiobarbituric acid reactive substances (*TBARS*) values, approximately two-fold lower compared to the control at 7 days and 14 days. These findings suggest that CZ and MC could be utilised as antioxidants to improve the storability of black goat extract.

Keywords

antioxidant; black goat extract; functional food; lipid oxidation; *Chrysanthemum zawadskii*; *Momordica charantia*; quality

With the growing interest in functional foods and natural health ingredients, there has been a renewed focus on the traditional animal component, black goat, and the development of value-added products utilising it. The Korean native black goat (*Capra hircus coreanae*) is commonly found in Korea and has traditionally been used in herbal medicine due to its health-promoting properties [1, 2]. Black goat possesses high nutritional value as it contains various nutrients such as protein, essential amino acids, vitamins, and minerals [3]. Nonetheless, a notable limitation in its use is stability, which is susceptible to oxidation, microbial growth, and chemical changes in bioactive compounds even after processing, thereby complicating the maintenance of quality and long-term distribution [4].

The use of natural plant-based ingredients is increasingly recognised as a strategy to address these storage challenges and enhance the functional value of products [5]. Studies have shown that plants can enhance the flavour, nutritional, and pharmacological (such as flavonoid and polyphenol) properties of food ingredients, thus elevating the overall quality of the food and extending its shelf life [6, 7]. Passos et al. [8] found that green tea extract added to chicken patties inhibited lipid oxidation without altering sensory parameters, while Gao et al. [9] demonstrated that extracts from pine bark, pomegranate, and other plants reduced lipid oxidation in cold plasma-treated meat. The application of plant-based antioxidants can supplant synthetic additives, offering benefits for the development of functional foods that align with consumer preferences for health and natural preservation [10].

Momordica charantia (MC) is extensively cultivated in tropical and subtropical regions and

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belongs to the Cucurbitaceae family; it has been traditionally used for food and medicinal purposes in Asia and Africa [11, 12]. Additionally, MC is rich in phenolic acids (e.g., gallic acid, caffeic acid, and chlorogenic acid), flavonoids (e.g., kaempferol), and other polyphenolic compounds [13–15].

Chrysanthemum zawadskii (CZ) is a perennial herb indigenous to the mountainous and highland areas of East Asia and Russia, belonging to the Asteraceae family, and has been employed as a traditional medicine since ancient times. It contains high levels of phenolic acids (e.g., chlorogenic acid, caffeic acid), flavonoids (e.g., linarin, apigenin), and other polyphenolic compounds [16].

The polyphenolic and flavonoid constituents in both plants are effective antioxidants, scavenging reactive oxygen species (ROS) and inhibiting lipid oxidation [17, 18]. Consequently, CZ and MC serve as natural antioxidants that enhance preservation by inhibiting lipid oxidation, a significant issue during food storage; however, research on their impact on quality and storability, when incorporated into foods, is scant.

Consequently, this study investigated the antioxidant properties of CZ and MC and their impact on quality and lipid oxidation when integrated into black goat extract.

MATERIALS AND METHODS

Preparation of water extracts of plants

CZ and MC were obtained in the dried form from a herbal medicine store in Geumsan (South Korea), pulverised, and the extraction process was performed with minor modifications based on previous studies for maximum extraction of bio-active compounds [19, 20]. The extracts were prepared by combining the plant material with distilled water at a ratio of 1:10 and heated in a water bath at 70 °C (MC) and 90 °C (CZ) for 4 h. The extracts were subsequently filtered. The first filtration used a Miracloth filter (Millipore, Burlington, Massachusetts, USA). The second filtration was performed with a Whatman No. 2 filter (Whatman, Maidstone, United Kingdom). The filtrate was then freeze-dried and converted into powder.

Total phenolic contents

The lyophilised extracts of MC and CZ were resuspended in distilled water at concentrations of 1, 2, 4, 6, 8, 10, 20, 40, 60, 80, and 100 mg·ml^{-1}. Gallic acid (Duksan, Ansan, South Korea), used as the standard for the calibration curve, was prepared at concentrations ranging from 1 μg·ml^{-1} to 250 μg·ml^{-1}. A 40 μl aliquot of the diluted extract was combined with 80 μl of 2 mol·l^{-1} Folin-Ciocalteu reagent (Sigma Aldrich, St. Louis, Missouri, USA) and maintained at room temperature (20 ± 3 °C) for 3 min. Subsequently, 800 μl of 20% Na_2CO_3 was added, and the mixture was incubated in the dark at 37 °C for 30 min before spectral measurement at 765 nm using a spectrophotometer Mobi (MicroDigital, Seongnam, South Korea).

The total phenolic content (*TPC*) was quantified using the established standard curve with gallic acid, and the standard curve was as follows:

$$y = 0.0166x + 0.1056;\ (R^2 = 0.9911) \quad (1)$$

The results are expressed in grams of gallic acid equivalents (GAE) per kilogram of sample.

Total flavonoid contents

The extracts of MC and CZ were prepared at concentrations identical to those used for *TPC* assessment and further diluted to levels ranging from 1 μg·ml^{-1} to 250 μg·ml^{-1} for analysis using naringin (Supelco, Bellefonte, Pennsylvania, USA) as the standard curve. A 100 μl volume of the diluted extract was mixed with 1 ml of diethylene glycol and 100 μl of 1 mol·l^{-1} NaOH, incubated for 1 h in the dark at 37 °C, and assessed at 420 nm using a spectrophotometer Mobi.

The total flavonoid content (*TFC*) was quantified using the established standard curve with gallic acid, and the standard curve was as follows:

$$y = 0.0009x + 0.0529;\ (R^2 = 0.9907) \quad (2)$$

The results are expressed in grams of naringin equivalents (NE) per kilogram of sample.

Radical scavenging activity

2,2-Diphenyl-1-picrylhydrazyl (DPPH, Biozoa, Seoul, South Korea) and 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS, Sigma Aldrich), respectively, were used to determined radical scavenging activity (RSA_{DPPH} and RSA_{ABTS}, respectively).

RSA_{DPPH} was assessed by mixing 250 μl of distilled water with 500 μl of 0.2 mol·l^{-1} DPPH solution and 250 μl of the sample, allowing the reaction to proceed for 30 min in a dark room at room temperature (20 ± 3 °C), and subsequently measuring absorbance at 517 nm using a spectrophotometer Mobi.

The ABTS was used to determine RSA_{ABTS}. ABTS reagent was prepared by mixing 0.014 mol·l^{-1} ABTS solution with 0.0049 mol·l^{-1} potassium persulfate solution in a 1 : 1 ratio and

incubating in a dark room (20 ± 3 °C) for 12 h before dilution with ethanol to achieve an absorbance of 0.70 ± 0.02 at 734 nm. A 20 μl sample was then mixed with 3 ml of the diluted ABTS reagent, reacted for 5 min in the dark, and measured at 734 nm using a spectrophotometer Mobi.

RSA was quantified as the concentration required to reduce the free radical activity by 50 % (RC_{50}) and expressed in milligrams per millilitre of sample. Ascorbic acid was used as a positive control.

Preparation of black goat extract

For the preparation of black goat extract, eviscerated black goat meat, bones, sub-materials (Sejong, South Korea), purified water and the dried plants (CZ and MC) were heated (120 °C, 12 h) as outlined in Tab. 1. The resultant mixture was then subjected to a hydraulic press, pressurising to separate the liquid from solid materials. After removing the surface oil, the extract underwent primary sterilisation and was subsequently packaged in 115 ml retort pouches for secondary sterilisation.

Chemical composition

The chemical composition was measured following the AOAC methods [21]. The parameters evaluated included moisture, determined by the atmospheric pressure drying method (AOAC 925.10); ash, quantified by the direct ash method (AOAC 923.03); fat, extracted using the Folch method (AOAC 960.39); and protein, measured through the Dumas method (AOAC 990.03). pH was determined with a pH meter Orion Star A211 (Thermo Fisher Scientific, Waltham, Massachusetts, USA). The salinity of the black goat extract was assessed using a salinity meter PAL-03S (ATAGO, Tokyo, Japan) and expressed as a percentage of sodium chloride. Sugar content was determined using a sugar content meter PAL-1 (ATAGO) and expressed as a percentage Brix.

Mineral analysis

The mineral analysis of black goat extract was performed using inductively coupled plasma-optical emission spectrometry (ICP-OES). The sample was digested using a microwave digestion system UltraWAVE (Milestone, Sorisole, Italy) with nitric acid at 220 °C for 30 min. The optimal operating parameters for the ICP-OES instrument Spectro ARCOS (SPECTRO Analytical Instruments, Kleve, Germany) were as follows: radio frequency power (1 300 W), spray chamber (cyclonic spray chamber), plasma gas flow (12.0 l·min^{-1}), nebuliser gas flow (0.8 l·min^{-1}), auxiliary gas flow (0.8 l·min^{-1}), and wavelengths (Ca 324.754 nm; Cu 324.754 nm; Fe 259.941 nm; K 766.491 nm; Mg 280.270 nm; Mn 257.611 nm; Na 589.592 nm; Zn 213.856 nm; P 178.287 nm). The measured mineral content was expressed as milligrams per kilogram of sample.

Thiobarbituric acid reactive substances

To assess the lipid oxidation in black goat extract, samples were stored under accelerated test conditions (room temperature (20 ± 3 °C), humidity (60 ± 5 %), dark room, airtight box) and evaluated at 0, 7, and 14 days. Thiobarbituric acid reactive substances (*TBARS*) were quantified by homogenising 10 ml of sample with 10% perchloric acid for 15 min and 25 ml of distilled water using vortexing and filtering through Whatman No. 2 filter paper. In the subsequent steps, 5 ml of the filtrate and 5 ml of 2-thiobarbituric acid (Sigma Aldrich) were mixed and incubated in a cool, dark environment for 16 h, followed by measurement at 529 nm using a spectrophotometer Mobi.

TBARS are expressed as milligrams of malondialdehyde (MDA) per kilogram of sample.

Statistical analysis

All measurements were conducted at least three times, and the statistical significance was assessed using the IBM SPSS (28.0) software (IBM, Armonk, New York, USA). Statistical analyses involved One-way ANOVA, with subsequent post-hoc tests using Tukey's test.

Tab. 1. Formulation of black goat extract supplemented with *Chrysanthemum zawadskii* and *Momordica charantia*.

	Treatment			
	CON	CZ1	MC1	CZ1MC1
Black goat meat [%]	20	20	20	20
Jujube [%]	9	9	9	9
Onion [%]	9	9	9	9
Malt [%]	6	6	6	6
Bean powder [%]	6	6	6	6
Distilled water [%]	50	50	50	50
Total [%]	100	100	100	100
Supplement				
Dried CZ [g·kg^{-1}]	–	10	–	10
Dried MC [g·kg^{-1}]	–	–	10	10

CON – control, CZ – *Chrysanthemum zawadskii*, MC – *Momordica charantia.*

RESULTS AND DISCUSSION

Antioxidant activity

To analyse the antioxidant functionality of CZ and MC extracts, measurements of *TPC*, *TFC*, ABTS and DPPH radical scavenging activities were conducted (Fig. 1, Tab. 2). The *TPC* in the CZ extract was 28.74 g·kg^{-1} (expressed as GAE), approximately 5 times higher than in the MC extract (5.73 g·kg^{-1}). Similarly, the *TFC* in the CZ extract was 509.86 g·kg^{-1} (expressed as NE), roughly 12 times higher than in the MC extract (39.86 g·kg^{-1}). It has been established that phenolic and flavonoid components possess potent antioxidant properties [17, 18]. ABTS and DPPH radical scavenging activities were assessed to evaluate the antioxidant capabilities, using ascorbic acid, a well-known antioxidant, as a reference. The efficacy was quantified as RC_{50}, with lower values indicating greater antioxidant activity. The RC_{50} values of ascorbic acid in both the ABTS and DPPH assays were significantly lower compared to those of the extracts. Additionally, the CZ extract exhibited lower RC_{50} values than the MC extract, suggesting superior antioxidant activity. Despite these results, the antioxidant efficacy of the CZ and MC extracts did not match that of ascorbic acid, although the CZ extract demonstrated higher antioxidant performance than the MC extract. Rosemary extract, predominantly employed as an antioxidant in meat and oil products, was found by El Boukhari and Fatimi [22], Zhang et al. [23] to inhibit DPPH free radicals by 50 % at a concentration of 0.49 mg·ml^{-1} and to substantially diminish lipid peroxidation when included in raw chicken. The RC_{50} value of the CZ extract was comparable to that of the rosemary extract, indicating a potential for the CZ extract to mitigate lipid oxidation in food products due to its antioxidant properties.

Quality and lipid oxidation of black goat extract

Tab. 3 presents the chemical composition of black goat extracts formulated with CZ and MC. Moisture content was significantly higher in CON and lower in the CZ1MC1 treatment ($p < 0.05$).

Tab. 2. Total phenolic content, total flavonoid content and antioxidant activity of *Chrysanthemum zawadskii* and *Momordica charantia* extracts.

	Ascorbic acid	CZ extract	MC extract
TPC [g·kg^{-1}]	–	28.74 ± 1.16 ^{a}	5.73 ± 0.48 ^{b}
TFC [g·kg^{-1}]	–	509.86 ± 42.81 ^{a}	39.86 ± 3.80 ^{b}
ABTS RC_{50} [mg·ml^{-1}]	0.51 ± 0.02 ^{c}	14.67 ± 0.50 ^{b}	26.30 ± 0.85 ^{a}
DPPH RC_{50} [mg·ml^{-1}]	0.06 ± 0.00 ^{c}	0.94 ± 0.02 ^{b}	10.21 ± 0.40 ^{a}

Values are expressed as mean ± standard deviation. Means within a row with different superscripts differ significantly ($n = 3$, $p < 0.05$).
CZ – *Chrysanthemum zawadskii*, MC – *Momordica charantia*, *TPC* – total phenolic content (expressed as grams of gallic acid equivalents), *TFC* – total flavonoid content (expressed as grams of naringin equivalents), ABTS RC_{50} and DPPH RC_{50} – extract concentration required to reduce the free radical activity by 50 % determined by ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) and DPPH (2,2-diphenyl-1-picrylhydrazyl) based assay, respectively.

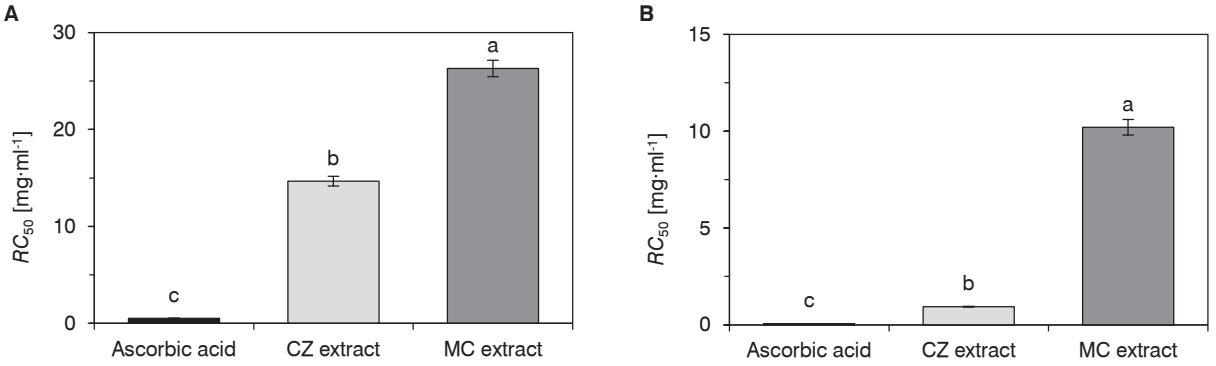


Fig. 1. Antioxidant capability of *Chrysanthemum zawadskii* and *Momordica charantia* extracts.

A – ABTS radical scavenging activity, B – DPPH radical scavenging activity.
Means with differing letters above bars are significantly different ($n = 3$, $p < 0.05$).
CZ – *Chrysanthemum zawadskii*, MC – *Momordica charantia*, RC_{50} – extract concentration required to reduce the free radical activity by 50 %.

Tab. 3. Chemical composition of black goat extract supplemented with *Chrysanthemum zawadskii* and *Momordica charantia*.

	CON	CZ1	MC1	CZ1MC1
Moisture [%]	91.6 ± 0.1 a	89.9 ± 0.0 c	90.8 ± 0.1 b	88.9 ± 0.2 d
Protein [%]	2.9 ± 0.0 c	3.2 ± 0.0 b	3.2 ± 0.0 b	3.6 ± 0.0 a
Fat [%]	0.7 ± 0.0 b	1.2 ± 0.0 a	0.8 ± 0.0 b	1.6 ± 0.0 a
Ash [%]	0.4 ± 0.0 c	0.5 ± 0.1 bc	0.5 ± 0.1 ab	0.6 ± 0.0 a

Values are expressed as mean ± standard deviation. Means within a row with different superscripts differ significantly ($n = 3$, $p < 0.05$).
CZ – *Chrysanthemum zawadskii*, MC – *Momordica charantia,* CON – control, samples without either CZ or MC, CZ1 – samples supplemented with dried CZ, MC1 – samples supplemented with dried MC, CZ1MC1 – samples supplemented with dried CZ and MC.

Conversely, protein, fat and ash contents were significantly lower in CON ($p < 0.05$). These results suggest that the extract was concentrated due to the increased solids content and decreased moisture content in the solvent caused by the dried CZ and MC.

Tab. 4 details the mineral content of the CZ and MC extracts. The mineral levels of treatments containing CZ and MC and black goat extract, according to the experimental design, were quantified in Tab. 5. In the treatment group CZ1MC1, Mn exhibited a significantly higher value ($p < 0.05$), whereas six minerals (Ca, Fe, Mg, K, Na, P) demonstrated no significant difference compared to CON ($p > 0.05$). Calcium was quantified at 3 547.55 mg·kg^{-1} in the CZ extract

Tab. 4. Mineral content in *Chrysanthemum zawadskii* and *Momordica charantia* extracts.

Mineral	CZ extract	MC extract
Ca [mg·kg^{-1}]	3 547.55 ± 532.16	696.00 ± 115.80
Cu [mg·kg^{-1}]	ND	ND
Fe [mg·kg^{-1}]	18.06 ± 1.11	93.41 ± 6.45
K [mg·kg^{-1}]	60 792.88 ± 1 430.61	78 917.44 ± 2 346.23
Mg [mg·kg^{-1}]	2 815.45 ± 100.21	6 903.14 ± 121.52
Mn [mg·kg^{-1}]	423.42 ± 9.48	23.70 ± 3.86
Na [mg·kg^{-1}]	384.88 ± 25.29	104.04 ± 2.84
P [mg·kg^{-1}]	6 386.24 ± 666.00	13 667.13 ± 2 149.99
Zn [mg·kg^{-1}]	48.12 ± 4.97	83.90 ± 11.79

Values are expressed as mean ± standard deviation. Means within a row with different superscripts differ significantly ($n = 3$, $p < 0.05$). CZ – *Chrysanthemum zawadskii*, MC – *Momordica charantia*, ND – not detected.

Tab. 5. Mineral content of black goat extract supplemented with *Chrysanthemum zawadskii* and *Momordica charantia*.

Mineral	CON	CZ1	MC1	CZ1MC1
Ca [mg·kg^{-1}]	2 264.72 ± 87.03 a	2 287.97 ± 158.23 a	1 699.75 ± 83.90 b	2 170.40 ± 117.67 a
Cu [mg·kg^{-1}]	ND	ND	ND	ND
Fe [mg·kg^{-1}]	59.75 ± 4.13 a	56.79 ± 3.92 a	45.99 ± 3.18 b	63.24 ± 3.05 a
K [mg·kg^{-1}]	25 035.09 ± 2 923.69	25 744.06 ± 2 371.34	29 062.19 ± 2 872.10	25 043.75 ± 1 446.50
Mg [mg·kg^{-1}]	2 053.92 ± 30.94 a	1 964.04 ± 29.80 b	2 096.87 ± 40.43 a	2 055.93 ± 10.35 a
Mn [mg·kg^{-1}]	17.00 ± 1.51 c	22.12 ± 2.39 b	14.64 ± 2.43 d	30.86 ± 2.22 a
Na [mg·kg^{-1}]	1 257.23 ± 44.15 b	1 317.03 ± 46.24 b	1 730.73 ± 60.77 a	1 163.56 ± 60.07 b
P [mg·kg^{-1}]	6 088.75 ± 690.13	5 705.09 ± 41.85	6 385.33 ± 608.65	5 500.16 ± 40.35
Zn [mg·kg^{-1}]	41.23 ± 3.69 b	28.63 ± 1.65 c	54.91 ± 5.18 a	33.59 ± 1.45 c

Values are expressed as mean ± standard deviation. Means within a row with different superscripts differ significantly ($n = 3$, $p < 0.05$).
CZ – *Chrysanthemum zawadskii*, MC – *Momordica charantia*, CON – control, samples without either CZ or MC, CZ1 – samples supplemented with dried CZ, MC1 – samples supplemented with dried MC, CZ1MC1 – samples supplemented with dried CZ and MC, ND – not detected.

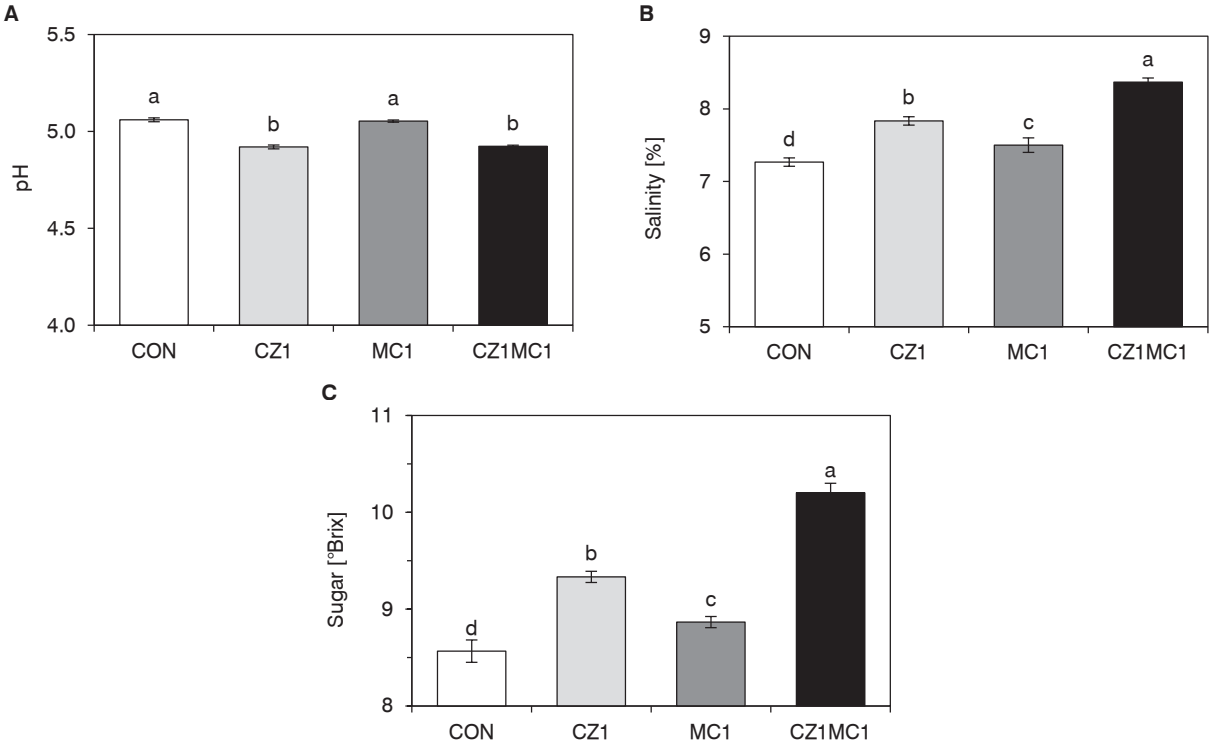


Fig. 2. pH, salinity, and sugar content of black goat extract supplemented with *Chrysanthemum zawadskii* and *Momordica charantia*.

A – pH, B – salinity, C – sugar content.
Means with different letters above bars differ significantly ($n = 3$, $p < 0.05$).
CZ – *Chrysanthemum zawadskii*, MC – *Momordica charantia,* CON – control, samples without either CZ or MC, CZ1 – samples supplemented with dried CZ, MC1 – samples supplemented with dried MC, CZ1MC1 – samples supplemented with dried CZ and MC.

and 696.00 mg·kg^{-1} in the MC extract, influencing the significantly lowered Ca in MC1. This study identified nine essential minerals which are crucial for various biological processes [24, 25]. Notably, Manganese, which plays a significant role in maintaining bone integrity and function, was recently highlighted as particularly important [26]. Based on these findings, the utility of CZ and MC as components for enhancing the functionality of black goat extract was established, suggesting their potential in the development of functional products by increasing the protein and manganese content from a nutritional perspective.

Fig. 2 illustrates the pH, salinity, and sugar content of black goat extracts produced with CZ and MC.

The pH values were significantly lower in treatments CZ1 and CZ1MC1. Lee [27] observed that

Tab. 6. Lipid oxidation of black goat extract supplemented with *Chrysanthemum zawadskii* and *Momordica charantia*.

Storage time	CON	CZ1	MC1	CZ1MC1
	TBARS [mg·kg^{-1}]			
0 days	0.38 ± 0.04^{bc}	0.47 ± 0.02^{a}	0.37 ± 0.05^{c}	0.47 ± 0.02^{a}
7 days	0.93 ± 0.05^{a}	0.62 ± 0.05^{b}	0.45 ± 0.03^{c}	0.52 ± 0.02^{c}
14 days	2.97 ± 0.08^{a}	1.80 ± 0.08^{b}	1.76 ± 0.03^{b}	1.67 ± 0.08^{b}

Values are expressed as mean ± standard deviation. Means within the same row with different superscripts exhibit significant differences ($n = 3$, $p < 0.05$).
TBARS – thiobarbituric acid reactive substance (expressed as milligrams of malondialdehyde), CZ – *Chrysanthemum zawadskii*, MC – *Momordica charantia,* CON – control, samples without either CZ or MC, CZ1 – samples supplemented with dried CZ, MC1 – samples supplemented with dried MC, CZ1MC1 – samples supplemented with dried CZ and MC.

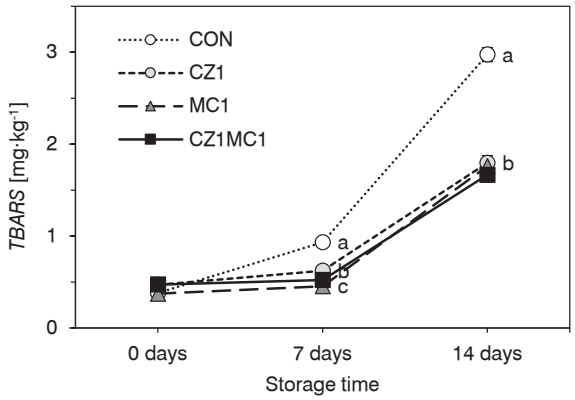


Fig. 3. Thiobarbituric acid reactive substance value of black goat extract supplemented with *Chrysanthemum zawadskii* and *Momordica charantia*.

Means possessing different letters differ significantly ($n = 3$, $p < 0.05$).
TBARS – thiobarbituric acid reactive substance (expressed as milligrams of malondialdehyde), CZ – *Chrysanthemum zawadskii*, MC – *Momordica charantia,* CON – control, samples without either CZ or MC, CZ1 – samples supplemented with dried CZ, MC1 – samples supplemented with dried MC, CZ1MC1 – samples supplemented with dried CZ and MC.

the inclusion of CZ powder in the production of yanggaeng, the traditional Korean confectionery, led to a decrease in pH as the quantity added increased. This study suggests that the incorporation of CZ reduced the pH of black goat extract.

Salinity and sugar content were markedly higher in CZ1MC1 and lower in CON. With respect to sugar content, *Chrysanthemum zawadskii*, being rich in polysaccharides [28], is believed to contribute to the observed increase in sugar content. Since degrees Brix are directly proportional to total sugar content, the CZ1MC1 treatment group is expected to enhance sugar content, thus promoting consumption [29]. Salinity was measured using the electrical conductivity method, influenced by Na^+, Cl^-, and K^+ ions. The addition of CZ and MC has been shown to elevate salinity levels, which is attributed to the dissolution of solid components from CZ and MC into the black goat extract, resulting in considerably higher values in CZ1MC1.

Tab. 6 and Fig. 3 present the *TBARS* values of black goat extracts formulated with the addition of CZ and MC over the storage period (0, 7 and 14 days). When *TBARS* levels were measured, the CON group exhibited significantly higher values from day 7, achieving approximately 2.97 $mg \cdot kg^{-1}$ (expressed as MDA) at day 14, which was about 1.0 $mg \cdot kg^{-1}$ higher than those observed in other treatment groups. MDA, a by-product of lipid oxidation, serves as a biomarker for assessing the oxidative deterioration of fats [30]. Hence, it appears that the addition of CZ and MC inhibits lipid oxidation in black goat extract owing to their previously confirmed antioxidant properties. This indicates that CZ and MC might be incorporated into foods as natural antioxidants.

CONCLUSION

In conclusion, this study demonstrated that the addition of CZ and MC could inhibit lipid oxidation in black goat extract, which is attributed to their antioxidant properties. As evidenced by the study, CZ and MC extracts displayed antioxidative activity in assays for DPPH and ABTS radical scavenging. The *TBARS* analysis of black goat extract revealed a notably lower rate of lipid oxidation in the treatment groups compared to the CON, attributable to the antioxidant functions of CZ and MC. These findings suggest that CZ and MC could enhance food storage stability and serve as functional food ingredients as natural antioxidants. The inclusion of CZ and MC resulted in reduced moisture content and increased protein. This alteration impacted the mineral profile, pH, salinity, and sugar content. It is believed that this would enhance the functionality because of the increase in Mn and improve palatability due to heightened sweetness. Based on these findings, it is suggested that CZ and MC could be utilised as antioxidants in black goat extract and potentially in goat meat products.

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