Food Sci. Biotechnol. Vol. 15, No. 2, pp. 264 ~ 269 (2006)

Food Science and Biotechnology

Rheological Properties of Concentrated Dandelion Leaf Extracts by Hot Water or Ethanol

Ok-Hwan Lee, Sung-Kwon Ko[1], and Boo-Yong Lee*

Graduate School of Complementary Alternative Medicine, Pochon CHA University, Seongnam, Kyonggi 463-836, Korea

[1]Department of Oriental Medical Food & Nutrition, Semyung University, Jechon, Chungbuk 390-711, Korea

Abstract Basic rheological data of dandelion leaf concentrates were determined to predict processing aptitude and usefulness of dandelion leaf concentrates as functional food materials. Hot water and 70% ethanol extracts of dandelion leaves were concentrated at 5, 20, and 50 Brix, and their static and dynamic viscosities, and Arrhenius plots were investigated. Most concentrated dandelion leaves extracted with hot water and 70% ethanol showed flow behaviors close to Newtonian fluid based on power law model evaluation. Apparent viscosity of concentrated dandelion leaves extracted with hot water and 70% ethanol decreased with increasing temperature. Yield stresses of concentrated dandelion leaves extracted with hot water and 70% ethanol by Herschel-Bulkley model application were 0.020-0.641 and 0.017-0.079 Pa, respectively. Activation energies of concentrated dandelion leaves extracted with hot water and 70% ethanol were $2.102\text{-}32.669\times10^3$ and $1.657\text{-}5.382\times10^3$ J/mol· kg with increasing concentration, respectively. Loss modulus (G") predominated over storage modulus (G') at all applied frequencies, showing typical flow behavior of low molecular solution. G' and G" of concentrated dandelion leaves extracted with hot water slowly increased with increasing frequency compared to those of concentrated dandelion leaves extracted with 70% ethanol.

Keywords: concentrated dandelion leaf extracts, rheological properties, static viscosity, dynamic viscosity, Arrhenius plotting

Introduction

Dandelion (*Taraxacum officinale*) has been widely used as a remedy in traditional oriental medicine for its choleretic, diuretic, anti-rheumatic, anti-viral, and anti-inflammatory properties (1-2), and its bitter tasting substances are assumed to exert the therapeutic properties. The major physiologically active substances of dandelion are sesquiterpene, lactones, taraxacoside, triterpenes, phytosterols, phenolic acid, and flavonoid (3-5).

Dried dandelion leaf and root are sold as herbal tea, and the powdered root is sold in a capsule form. Roasted dandelion root is used as a coffee substitute, and fresh dandelion leaf is used as an ingredient of *kimchi* (6).

Several reports have shown that dandelion induces cytotoxicity through TNF-α and IL-1α secretions in Hep G2 cells (7). Further studies have reported antioxidative activities such as reactive radical and nitric oxide-scavenging activities of dandelion flower extract *in vitro* (8), changes of hepatic antioxidant enzyme activities and lipid profile in streptozotocin-induced diabetic rats by supplementation of dandelion water extract (9), growth promotion effect of some bifidobacteria with dandelion root (10), and optimum extraction condition for supercritical fluid extraction of dandelion leaves (11). Nevertheless, the basic rheological properties of dandelion leaf extract and concentrate required confirming the processing and development of products have not yet been reported.

Recently, there has been increasing demand for dandelion leaf and root as ingredients in foodstuffs, food additives, and functional food materials. The aim of this study was to provide basic data on the rheological properties of concentrated dandelion leaf extracts for the prediction of the processing aptitude and usefulness of dandelion leaf as a foodstuff ingredient and functional food material. Investigations were made on the static viscosity, dynamic viscosity, and Arrhenius plot of concentrated dandelion leaf extracted with hot water or 70% ethanol.

*Corresponding author: Tel: 82-31-725-8371; Fax: 82-31-725-8350
E-mail: bylee@cha.ac.kr
Received December 16, 2005; accepted March 21, 2006

Materials and Methods

Materials Fresh dandelion leaves harvested at Gyeongbuk in 2003 (Miju-food, Gyeongbuk, Korea) were washed with tap water and dried at 40±5°C.

Roasting and Grinding Dried dandelion leaves were roasted for development of good flavor and desirable organoleptic characteristics using a rotary roaster (Probat Co., Stuttgart, Germany) at 130°C for 3 min. The dried and roasted leaves were ground to 20-30 mesh by a grinder (IKA M 20; Ika, Staufen, Germany).

Preparation of dandelion leaf concentrates by solvent extraction Dried and roasted dandelion leaves (750 g each) were refluxed with 50 volumes (v/w) of distilled water (100°C) and 70% ethanol (80°C) for 3 hr, and the extraction was repeated three times. The extract was centrifuged at 10,000×g for 30 min. A portion of the supernatant was filtered through a filter paper (Whatman No. 2) and concentrated to remove the ethanol at 5, 20 (dried and roasted), and 50 Brix using a vacuum evaporator at 40°C.

Measurement of rheological parameters The static and dynamic viscosities were measured with a controlled-stress rheometer (Carri-Med CSL 100; TA Instruments, New Castle, DE, USA) at 5, 25, and 45°C using a cone-plate system (2°, 4 cm diameter, zero gap 500 μm). To describe the variations in the rheological properties of the concentrated dandelion leaf extracts under static viscosity, the data were fitted to the well-known power-law (Eq. 1) (12) and Herschel-Bulkley (Eq. 2) (13) models.

$\tau = K \cdot \dot{\gamma}^{n}$ (1)
$\tau = C + K \cdot \dot{\gamma}^{n}$ (2)

τ : shear stress (Pa)
$\dot{\gamma}$: shear rate (1/sec)
K : consistency index (Pa·sec^{n})
n : flow behavior index (dimensionless)
C : yield stress (Pa)

The effects of concentration and temperature on the apparent viscosity of the concentrated dandelion leaf extracts were analyzed by Arrhenius equations 3 and 4 (14, 15), respectively.

$$\eta_{app} = \eta_{\infty} \cdot \exp(B \cdot A) \quad (3)$$

$$\eta_{app} = \eta_{\infty} \cdot \exp(E_a/RT) \quad (4)$$

η_{app} : apparent viscosity (Pa·sec)
η_{∞} : infinite apparent viscosity (Pa·sec)
B : concentration dependency constant (dimensionless)
A : concentration (Brix)
E_a : activation energy for flow (J/mol·kg)
R : gas constant (J/K·mol·kg)
T : absolute temperature (K)

Dynamic viscosity was measured in the range of 0.1-10 Hz. Linear viscoelastic region was determined for each sample from stress sweeps at 5 Hz. Carri-Med data analysis software (version DATA V1.2.2.) was used to obtained the experimental data, storage modulus (G'), and loss modulus (G"). All experiments were conducted in triplicates.

Results and Discussion

Proximate composition of raw dandelion leaf The moisture content of raw dandelion leaf was 88.2% (16). Dried dandelion leaf and root comprised 21.60 and 11.80 % crude protein, 5.12 and 1.73% crude fat, 11.35 and 4.82 % crude ash, and 54.08 and 73.92% carbohydrate, respectively (17). The crude protein, fat, and ash contents were higher in leaf than root, while carbohydrate content was higher in root than leaf.

Extraction yield and free sugar contents of dandelion leaf extracts The extraction yields of hot water and 70% ethanol dandelion leaf extracts were 39.33 and 33.67%, respectively. Dandelion leaf hot water and 70% ethanol extracts comprised 1.65 and 1.38% fructose, 3.95 and 3.99% sucrose, and 8.01 and 7.74% glucose, respectively. Maltose was not detected in both extracts.

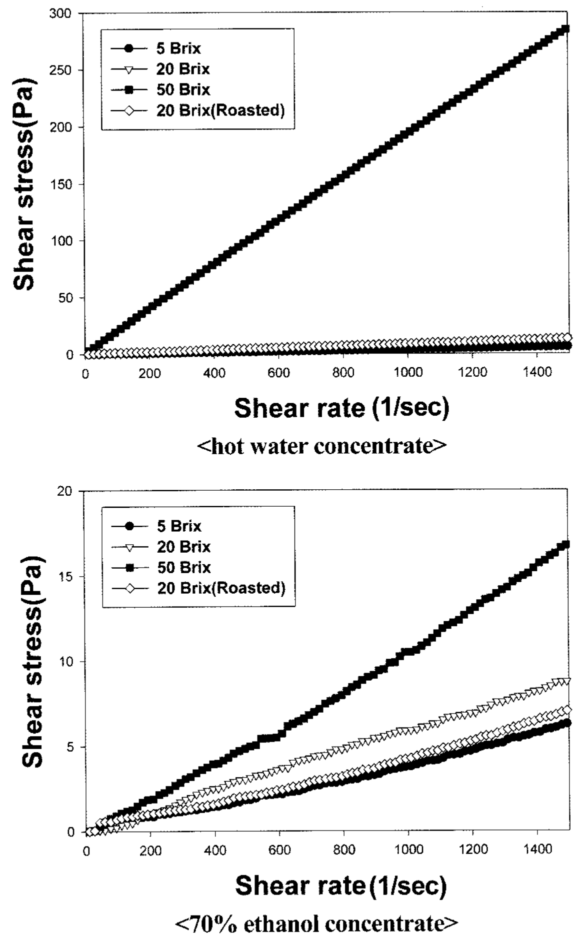

Fig. 1. Shear stress vs. shear rate plot of dandelion leaf concentrates extracted by hot water or 70% ethanol at 25°C.

Static viscosity properties The shear stress levels of concentrated dandelion leaves extracted with hot water and 70% ethanol at 25°C were measured by changing the shear rate from 0 to 1500 1/sec (Fig. 1). Flow behavior of concentrated dandelion leaf extracted with hot water at 25°C was similar to those measured at 5 and 45°C. The shear stresses of concentrated dandelion leaves extracted with hot water and 70% ethanol at 5, 20, and 50 Brix increased linearly with increasing shear rate as well as with increasing soluble solid content. In addition, the shear stresses of concentrated roasted dandelion leaves extracted with hot water and 70% ethanol at 20 Brix increased linearly with increasing shear rate.

Table 1 shows the application of power law and Herschel-Bulkley models to the rheological parameter values of concentrated dandelion leaves extracted with hot water and 70% ethanol. Most concentrated dandelion leaves extracted with hot water and 70% ethanol showed flow property of typical Newtonian fluid (n=0.958-1.103) as revealed by power law model evaluation. The consistency index (K) decreased with temperature at the same concentration, whereas increased with concentration at the same temperature. Yield stress values of concentrated dandelion leaves extracted with hot water and 70% ethanol by Herschel-Bulkley model evaluation were in the range of 0.020-0.641 and 0.017-0.079 Pa, respectively.

Table 1. Rheological parameters of dandelion leaf concentrates by solvents extraction

Extraction solvents	Conc. (Brix)	Temp. (°C)	Power law model			Herschel-Bulkley model			
			n (-)	K (Pa·sec^n)	r[1)]	n (-)	K (Pa·sec^n)	C (Pa)	r[1)]
Hot water	5	5	1.062	0.002	0.97	1.076	0.002	0.064	0.97
		25	1.070	0.002	0.97	1.122	0.001	0.043	0.98
		45	1.071	0.003	0.98	1.222	0.001	0.020	0.98
	20	5	0.980	0.009	0.98	1.044	0.002	0.139	0.98
		25	0.990	0.009	0.97	1.055	0.005	0.094	0.99
		45	1.005	0.005	0.97	1.156	0.002	0.023	0.99
	50	5	0.958	0.962	0.99	0.961	0.948	0.641	0.99
		25	0.959	0.254	0.99	0.971	0.235	0.483	0.99
		45	0.962	0.176	0.99	1.004	0.121	0.217	0.99
	20 (roasted)	5	1.054	0.006	0.96	1.087	0.037	0.188	0.99
		25	1.050	0.007	0.98	1.036	0.008	0.139	0.99
		45	1.070	0.005	0.97	1.166	0.002	0.061	0.99
70% ethanol	5	5	1.091	0.001	0.97	1.091	0.001	0.017	0.97
		25	1.083	0.002	0.96	1.085	0.002	0.026	0.98
		45	1.103	0.002	0.98	1.225	0.001	0.076	0.98
	20	5	1.019	0.002	0.96	1.049	0.001	0.055	0.97
		25	1.029	0.004	0.96	1.082	0.003	0.013	0.98
		45	1.039	0.003	0.97	1.178	0.000	0.068	0.97
	50	5	1.005	0.016	0.97	1.006	0.008	0.059	0.96
		25	1.011	0.016	0.97	1.018	0.003	0.079	0.97
		45	1.038	0.005	0.98	1.074	0.004	0.017	0.98
	20 (roasted)	5	1.030	0.003	0.97	1.120	0.002	0.049	0.98
		25	1.066	0.019	0.95	1.138	0.004	0.065	0.99
		45	1.068	0.003	0.96	1.238	0.001	0.063	0.98

[1)]Correlation coefficient.

Flow behaviors of all concentrated roasted dandelion leaves extracted with hot water and 70% ethanol were close to Newtonian fluid (n=1.030-1.070) as revealed by power law model evaluation. The viscosity of concentrated roasted dandelion leaf extracted with hot water at 20 Brix was lower than that of hot water extract. At 20 Brix flow properties of concentrated roasted dandelion leaf extracts were not similar to those of concentrated dried dandelion leaves extracted with hot water and 70% ethanol. In addition, at 50 Brix flow properties of concentrated dandelion leaf extracted with hot water were not similar to those observed in concentrated dandelion root extracted with hot water (18). Although the viscosity of concentrated dandelion leaf extracted with hot water was higher than that of concentrated dandelion root extracted with hot water, flow properties of concentrated dandelion leaf extracted with hot water at 50 Brix were similar to those of Newtonian fluid in that concentrated dandelion root extracted with hot water was composed of relatively regular size macromolecules. On the other hand, the molecule size of concentrated dandelion root extracted with hot water ranged from small to macromolecules, indicating the flow property of a typical pseudoplastic fluid (18).

Effect of temperature on apparent viscosity The effect of temperature on apparent viscosities of concentrated dandelion leaves extracted with hot water and 70% ethanol were described by ln η_{app} vs. 1/T (Fig. 2). Normally, viscosity of a fluid, defined as the resistance against fluid flow, is affected by the binding between molecules that make up the solution or the relationship between the solvent and solute, with both factors affected by solution concentration and temperature. External energy supplied by heating to increase the temperature increases the energy of the molecules, which, in turn, increase the distance between molecules, thereby reducing the solution viscosity (14, 15)

Table 2 shows the values of η_∞ and E_a in the Arrhenius equation, $\eta_{app} = \eta_\infty \cdot \exp(E_a/RT)$. The activation energies of concentrated dandelion leaves extracted with hot water and 70% ethanol were in the ranges of $2.102\text{-}32.669\times10^3$ and $1.657\text{-}5.382\times10^3$ J/mol·kg with increasing concentration, respectively. The η_∞ values of concentrated dandelion leaves extracted with hot water and 70% ethanol were in the range of $1.710\text{-}0.001\times10^{-3}$ and $1.920\text{-}1.031\times10^{-3}$ Pa·sec

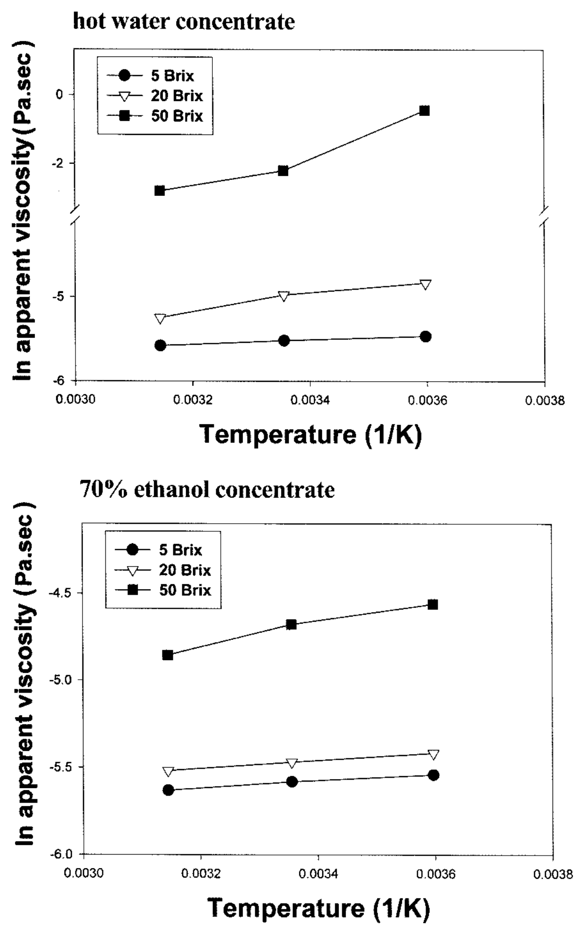

Fig. 2. Effect of temperature on apparent viscosity of dandelion leaf concentrates extracted by hot water or 70% ethanol at 1000 1/sec.

with increasing concentration, respectively. These results agreed with those of *Agastache rugosa* O. Kuntze hot water extract study (19) and study of rheological property of Roselle extract (14), which maybe due to the high dependence of molecular binding as well as solvent and solute binding at high concentration.

Effect of concentration on apparent viscosity The effects of concentration on apparent viscosity of the concentrates were described by the plot of ln η_{app} vs. concentrations at 1000 1/sec shear rate (Fig. 3). In general, η_∞ decrease with increasing temperature from 5 to 45°C. The effects at all temperatures and concentrations were described by $\eta_{app} = \eta_\infty \cdot \exp(B \cdot A)$ Arrhenius equation (Table 3). The B values of concentrated dandelion leaves extracted with hot water and 70% ethanol were in the ranges of 0.1193-0.0815 and 0.0227-0.0179 with increasing temperature, respectively. On the other hand, η_∞ of concentrated dandelion leaves extracted with hot water and 70% ethanol were in the ranges of 0.111469-0.001759 and 0.003213-0.003080 Pa·sec with increasing temperature, respectively.

Dynamic viscosity properties Most macromolecule solutions exhibited rheological responses of both solid-like and liquid-like characteristics (viscoelastic materials). The

Table 2. Effect of temperature on apparent viscosity of dandelion leaf concentrates by solvents extraction at 1000 1/sec

Extraction solvents	Conc. (Brix)	Temp. (K)	η_{app} (Pa·sec)	E_a ($\times 10^3$ J/mol·kg)	η_∞ ($\times 10^{-3}$ Pa·sec)	r[1)]
Hot water	5	278	0.004236			
		298	0.004021	2.102	1.710	0.99
		318	0.003776			
	20	278	0.007982			
		298	0.006914	7.583	0.307	0.95
		318	0.005265			
	50	278	0.720967			
		298	0.193527	32.669	0.001	0.94
		318	0.123888			
70% ethanol	5	278	0.003925			
		298	0.003771	1.657	1.920	0.99
		318	0.003585			
	20	278	0.004446			
		298	0.004222	1.877	1.975	0.99
		318	0.004014			
	50	278	0.010454			
		298	0.009299	5.382	1.031	0.98
		318	0.007785			

[1)]Correlation coefficient.

Table 3. Value of η_∞ and B of the dandelion leaf concentrates by solvents extraction at 1000 1/sec

Extraction solvents	Temp. (°C)	Conc. (Brix)	B	η_∞ (Pa·sec)	r[1)]
Hot water	5	5-50	0.1193	0.001469	0.95
	25	5-50	0.0897	0.001863	0.96
	45	5-50	0.0815	0.001759	0.94
70% ethanol	5	5-50	0.0227	0.003213	0.95
	25	5-50	0.0210	0.003133	0.95
	45	5-50	0.0179	0.003080	0.96

[1)]Correlation coefficient.

measurement of viscoelastic behavior of macromolecule solution is important in understanding and predicting the texture and flow properties during processing (20).

Figure 4 shows the changes in G' and G" as functions of frequency (ω) for concentrated dandelion leaves extracted with hot water and 70% ethanol at 50 Brix and 25°C. The results obtained at 25°C were similar to those at 5 and 45 °C. In the case of concentrated dandelion leaf extracted with 70% ethanol, G' and G" generally increased with increasing frequency; G" predominated over G' at all frequencies applied and showed typical flow behavior of low molecule solution. Similarly, G' and G" of concentrated dandelion leaf extracted with hot water slowly increased with increasing frequency; however, the

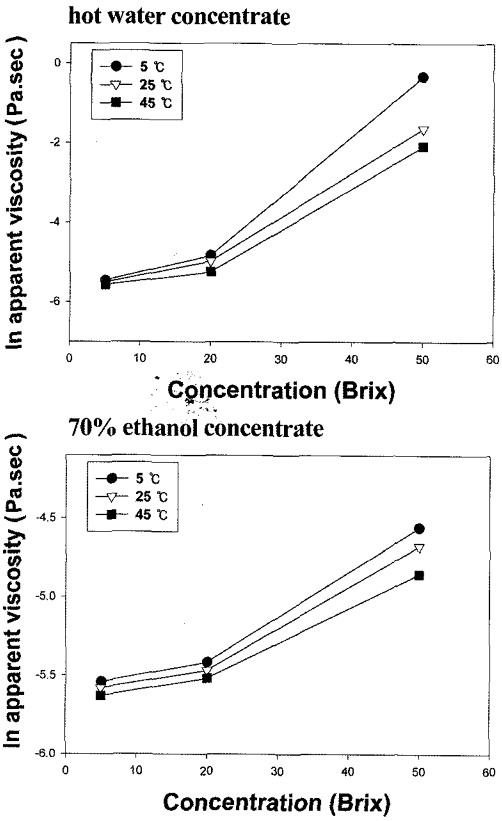

Fig. 3. Effect of concentration on apparent viscosity of dandelion leaf concentrates extracted by hot water or 70% ethanol at 1000 1/sec.

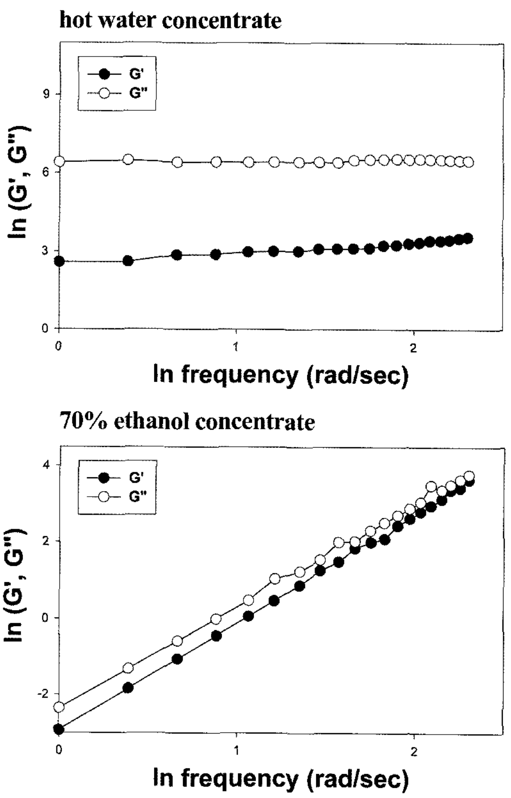

Fig. 4. ln (G', G") vs. ln frequency (rad/sec) of dandelion leaf concentrates by hot water or 70% ethanol extraction at 25°C.

cross over point of G' and G" shown in the concentrated dandelion root extracted with hot water (18) were not observed, because the macromolecule composition of concentrated dandelion root extracted with hot water was more complex than that of concentrated dandelion leaf extracted with hot water. On the other hands, G' and G" of concentrated dandelion leaf extracted with hot water slowly increased with frequency as compared to those of concentrated dandelion leaf extracted with 70% ethanol.

These results agreed with those of studies on the dynamic viscosity of ginseng extract (21). In general, at low frequencies, the flow behavior was controlled by the translational motion of the macromolecules, and G" was higher than G'. At higher frequencies, G' increased due to the macromolecular distortion and was close to or higher than that of G" (22, 23).

References

1. Bisset NG. Taraxaci radix cum herba. In: Herbal Drugs and Phytopharmaceuticals: A handbook for practice in scientific basis. CRC press, Boca raton, FL, USA. pp. 486-489 (1994)
2. Mascolo N, Autore G, Capasso F, Menghini A, Fasulo MP. Biological screening of Italian medicinal plants for anti-inflammatory activity. Phytother. Res. 1: 28-31 (1974)
3. Hu C, Kitts DD. Antioxidant, prooxidant and cytotoxic activities of solvent fractionated dandelion (*Taraxacum officinale*) flower extract in vitro. J. Agric. Food Chem. 51: 301-310 (2003)
4. Baba K, Abe S, Mizuno D Antitumor activity of hot water extract of dandelion, Taraxacum officinale-correlation between antitumor activity and timing of administration. Yakuga. Zasshi 101: 538-543 (1981)
5. Cordatos E. Taraxacum officinale. In: Murray M and izzorno J. A textbook of natural medicine. Bastyr University Press, Seattle, WA, USA. pp.148-160. (1992)
6. Williams CA, Goldstone F, Greenham J. Flavonoids, cinnamic acids and coumarins from the different tissues and medicinal preparations of *Taraxacum officinale*. Phytochemistry 42: 121-127 (1996)
7. Koo HN, Hong SH, Song BK, Kim CH, Yoo YH, Kim HM. *Taraxacum officinale* induces cytotoxicity through TNF-α and IL-1α secretion in Hep G2 cells. Life Sci. 71: 1149-1157 (2004)
8. Hu C, Kitts DD. Dandelion (Taraxacum officinale) flower extract suppresses both reactive oxygen species and nitric oxide and prevents lipid oxidation in vitro. Phytomedicine 12: 588-597 (2005)
9. Cho SY, Park JY, Park EM, Choi MS, Lee MK, Jeon SM, Jang MK, Kim MJ, Park YB. Alternation of hepatic antioxidant enzyme activities and lipid profile in streptozotocin-induced diabetic rats by supplementation of dandelion eater extract. Clin. Chim. Acta 317: 109-117 (2002)
10. Trojanova I, Rada V, Kokoska L, Vlkova E. The bifidogenic effect of *Taraxacum officinale* root. Fitoterapia 75: 760-763 (2004)
11. Simandi B, Kristo ST, Kery A, Selmeczi LK, Kmecz I, Kemeny S. Supercritical fluid extraction of dandelion leaves. J. Supercrit. Fluid 23: 135-142 (2002)
12. Rao MA, Antheswarn RC. Rheology of fluid in food processing. Food Technol. 36: 116-121 (1982)
13. Vitali AA, Rao MA. Flow properties of low-pulp concentration. J. Food Sci. 49: 882-888 (1984)
14. Hassan BH, Hobani AI. Flow properties of roselle (*Hibiscus sabdariffa* L.) extract. J. Food Eng. 35: 459-470 (1998)
15. Constenla DT, Lozano JE, Crapiste GH. Thermo physical properties of clarified juice as a function of concentration and temperature. J. Food Sci. 54: 663-668 (1989)
16. Food composition table sixth revision I. National rural living science institute, R.D.A. Suwon, Korea. pp. 112-113 (2001)
17. Kang MJ, Seo YH, Kim JB, Shin SR, Kim KS. The chemical composition of *Taraxacum officinale* consumed in Korea. Korean J. Soc. Food Sci. 16: 182-187 (2000)

18. Lee OH, Kang SN, Lee BY. Rheological properties of dandelion root concentrates by extraction solvents. Food Sci. Biotechnol. 15: 33-38 (2006)
19. Lee BY, Choi HS, Oh SR, Lee HK. Rheological characteristics of hot water concentrates from *Agastache rugosa* O. Kuntze. Food Sci. Biotechnol. 10: 294-298 (2001)
20. Han JS. Changes of dynamic viscoelastic properties of oxidized corn starch suspensions during heating and cooling. Food Sci. Biotechnol. 11: 231-237 (2002)
21. Yoo BS. Rheological properties of ginseng extracts. Food Sci. Biotechnol. 10: 633-637 (2001)
22. Yoo BS, Shon KJ, Chang YS. Effect of guar gum on rheological properties of acorn flour dispersions. Food Sci. Biotechnol. 14: 233-237 (2005)
23. Kim C, Yoo BS. Rheological properties of mustard suspension: Effect of concentration and temperature. Food Sci. Biotechnol. 13: 525-527 (2004)