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Short Communication

Anti-inflammatory effects of a *Houttuynia cordata* supercritical extract

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Anti-inflammatory effects of *Houttuynia cordata* supercritical extract (HSE) were investigated in a carrageenan-air pouch model. HSE (200 mg/kg, oral) suppressed exudation and albumin leakage, as well as inflammatory cell infiltration. Dexamethasone (2 mg/kg, i.p.) only decreased exudation and cell infiltration, while indomethacin (2 mg/kg, i.p.) reduced exudate volume and albumin content. HSE lowered tumor-necrosis factor (TNF)-α and nitric oxide (NO), as well as prostaglandin E_2 (PGE_2). Dexamethasone only reduced TNF-α and NO, while indomethacin decreased TNF-α and PGE_2. The suppressive activity of HSE on NO and PGE_2 production was confirmed in RAW 264.7. These results demonstrate that HSE exerts anti-inflammatory effects by inhibiting both TNF-α-NO and cyclooxygenase II-PGE_2 pathways.

Keywords: carrageenan, dexamethasone, *Houttuynia cordata extract*, indomethacin, inflammation

Traditionally, *Houttuynia* (*H.*) *cordata* Thunb has been used as an Oriental medicine for the treatment of inflammatory diseases such as ulcerative colitis [3]. Previous studies showed that *H. cordata* extracts had antiviral and antibacterial [2,6], antiallergic [5], antioxidant and antimutagenic activities [1].

The major constituents of *H. cordata* essential oil included methyl nonyl ketone, β-myrcene, β-pinene, α-pinene, α-terpineol and *n*-decanoic acid. The anti-inflammatory effects of the oil were also demonstrated [7].

In the present study, we investigated the anti-inflammatory activity of *H. cordata* supercritical extract (HSE) in both macrophages and a carrageenan-induced air pouch inflammation model [9,10].

The aerial part of *H. cordata* (10 kg) was extracted for 2 h under CO_2 supercritical conditions and the extract was collected as previously described [4]. The extract (yield = 150 g) was dissolved in soybean oil, and orally administered at 4 mL/kg.

For the effects of HSE on the secretion of inflammatory mediators, murine macrophages, RAW 264.7 cells (ATCC, USA; 1×10^6 cells/mL), were incubated with HSE (final 0.001 ~ 1%) and lipopolysaccharide (LPS, final 2.5 μg/mL) for 24 h. Levels of nitric oxide (NO) and prostaglandin E_2 (PGE_2) were measured by Griess reagent (Sigma, USA) and enzyme immunoassay (EIA) using a Correlate-EIA kit (Assay Designs, USA), respectively.

Male ICR mice (body weight 28 ~ 32 g; n = 8/group) were subcutaneously injected with 10 mL of sterile air into the back side to form a pouch [9,10]. After 2 and 5 days, the pouch was reinjected with 5 mL of air. Twenty four h after the final air injection, HSE (65 or 200 mg/kg) was orally administered, followed 1 h later by injection with 1 mL of lambda carrageenan (1% in saline; Sigma, USA) into the pouch. Dexamethasone (2 mg/kg; Sigma, USA) or indomethacin (2 mg/kg; Sigma, USA) were used as a positive control. The animal experiments were approved by the Institutional Animal Care and Use Committee of the Laboratory Animal Research Center, Chungbuk National University, Korea.

The pouch was washed with 1 mL of cold saline after 6 h, and the net volume of lavage fluid was recorded. Total numbers of inflammatory cells and albumin, a marker of vascular leakage, were determined using a coulter counter and a blood biochemistry analyzer, respectively. Tumor-necrosis factor (TNF)-α and interleukin (IL)-6 were analyzed using ELISA kits (Komabiotech, Korea). Tests of significance were performed using Duncan's multiple-range test after one-way ANOVA with $p < 0.05$ as a criterion of

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difference.

LPS treatment increased the secretion of both NO and PGE_2 from macrophages, up to 25~30 fold of control levels, which were substantially suppressed by HSE in a concentration-dependent manner (Table 1).

Injection of carrageenan into mouse air pouches significantly increased the exudate volume and the albumin concentrations in the exudates (Table 2). Oral treatment with HSE suppressed the carrageenan- induced increases in the exudate volume and albumin leakage at 200 mg/kg (46.7% and 61.7%, respectively). Intraperitoneal administration of dexamethasone and indomethacin also reduced both the exudate volumes (67.1% and 60.0% respectively) and albumin contents (45.1% and 47.4% respectively). Total white blood cells (WBC) in the exudates were greatly increased by carrageenan. Interestingly, infiltrating inflammatory cells were suppressed to half level by HSE (200 mg/kg) and dexamethasone, but not by indomethacin.

Carrageenan enormously enhanced major inflammatory cytokines TNF-α and IL-6 in the exudates (Table 3). Administration of HSE, dexamethasone and indomethacin significantly lowered the carrageenan-induced increases of TNF-α. In contrast, the increased IL-6 level was not significantly attenuated by any of the compounds. Interestingly, HSE nearly completely blocked the carrageenan-induced increases in both NO and PGE_2.

HSE attenuated not only the secretion of both major inflammatory mediators, NO and PGE_2 but also carrageenan-induced inflammatory responses in animals. The numbers of neutrophils and lymphocytes increased by carrageenan were reduced following treatment with HSE. This was an effect obtained by dexamethasone, but not by indomethacin (1~2 mg/kg) [8,10]. The corticosteroid-like effect of HSE was confirmed by its inhibitory action on TNF-α and NO. Therefore, the effect of HSE might be due to the suppression of signaling activity, as supported by the highly-sensitive suppression by HSE of NO secretion from macrophages.

HSE exhibited an additional inhibitory activity on the *in vitro* and *in vivo* release of PGE_2, suggesting that HSE directly inhibits COX II or deactivates inflammatory cells

Table 1. Effects of *Houttuynia cordata* supercritical extract (HSE) on the nitric oxide (NO) and prostaglandin E_2 (PGE_2) production from RAW 264.7 cells stimulated with lipopolysaccharide (LPS)

Treatment	NO		PGE_2	
	Conc. (μM)	Inhibition (%)	Conc. (μg/mL)	Inhibition (%)
Vehicle	1.20 ± 0.13	-	0.16 ± 0.03	-
LPS alone (2.5 μg/mL)	42.10 ± 7.21*	-	3.98 ± 0.48*	-
+HSE (0.001%)	14.80 ± 2.13†	66.7	3.74 ± 0.50	6.3
+HSE (0.01%)	14.5 ± 1.78†	67.5	3.01 ± 0.42†	25.4
+HSE (0.1%)	5.30 ± 0.90†	90.0	2.42 ± 0.45†	40.8
+HSE (1%)	2.00 ± 0.31†	98.0	0.91 ± 0.14†	80.4

*Significantly different from vehicle control ($p < 0.05$). †Significantly different from LPS alone ($p < 0.05$). Conc.: concentration.

Table 2. Effects of dexamethasone, indomethacin and HSE on carrageenan-induced exudation and inflammatory cell infiltration in mouse air pouches (n = 8)

Treatment	Exudate		Albumin		Cells (1,000/μL)			
	Volume (mL)	Inhibition (%)	Conc. (μg/mL)	Inhibition (%)	WBCs	Neutrophils	Monocytes	Lymphocytes
Vehicle	0.65 ± 0.12	-	0.81 ± 0.12	-	0.86 ± 0.21	0.17 ± 0.06	0.07 ± 0.02	0.55 ± 0.15
Carrageenan alone	1.17 ± 0.12*	-	2.14 ± 0.22*	-	8.80 ± 1.32*	1.01 ± 0.19*	0.46 ± 0.17*	7.07 ± 1.58*
+Dexamethasone	0.82 ± 0.08†	67.1	1.54 ± 0.43†	45.1	4.54 ± 1.19†	0.80 ± 0.23	0.20 ± 0.05†	2.51 ± 0.75†
+Indomethacin	0.86 ± 0.08†	60.0	1.51 ± 0.12†	47.4	8.54 ± 1.46	1.09 ± 0.29	0.38 ± 0.10	6.76 ± 2.08
+HSE (65 mg/kg)	1.07 ± 0.10	19.2	1.81 ± 0.43	24.8	8.13 ± 1.92	1.67 ± 0.28	0.74 ± 0.16	4.21 ± 1.39†
+HSE (200 mg/kg)	0.93 ± 0.04†	46.7	1.32 ± 0.21†	61.7	4.94 ± 1.44†	0.62 ± 0.21†	0.43 ± 0.17	3.85 ± 0.85†

*Significantly different from vehicle ($p < 0.05$). †Significantly different from carrageenan alone ($p < 0.05$).

Table 3. Effects of dexamethasone, indomethacin and HSE on the carrageenan-induced increases in cytokines and inflammatory mediators in mouse air pouch exudates (n = 8)

Treatment	TNF-α		IL-6		NO		PGE_2	
	Conc. (pg/mL)	Inhibition (%)	Conc. (pg/mL)	Inhibition (%)	Conc. (μM)	Inhibition (%)	Conc. (pmole/mL)	Inhibition (%)
Vehicle	5.0 ± 0.1	-	2.0 ± 0.4	-	0.391 ± 0.074	-	1,228.1 ± 43.8	-
Carrageenan alone	181.7 ± 50.0*	-	> 500.0*	-	0.774 ± 0.112*	-	1,439.5 ± 18.4*	-
+Dexamethasone	14.1 ± 5.8†	94.9	442.8 ± 53.0	11.5	0.054 ± 0.023†	188.0	1,411.3 ± 23.7	13.3
+Indomethacin	108.2 ± 22.4†	41.6	473.8 ± 20.5	5.3	0.663 ± 0.203	29.0	1,222.3 ± 11.0†	102.7
+HSE (65 mg/kg)	56.7 ± 15.2†	70.7	> 500.0	0.0	0.412 ± 0.125†	94.5	1,149.6 ± 51.6†	137.1
+HSE (200 mg/kg)	79.1 ± 20.1†	58.1	> 500.0	0.0	0.403 ± 0.187†	96.9	1,218.5 ± 41.2†	104.5

TNF-α: tumor-necrosis factor-α, IL-6: interleukin-6. *Significantly different from vehicle control ($p < 0.05$). †Significantly different from carrageenan alone ($p < 0.05$).

expressing COX II. In spite of a less-sensitive inhibition compared to NO from macrophages, *in vivo* production of PGE_2 was fully suppressed by HSE treatment. Such a difference between *in vitro* and *in vivo* studies may be due to the different stimulators, LPS and carrageenan, respectively.

Notably, our result show that HSE ($IC_{50} < 0.001\%$) was much superior to an aqueous extract ($IC_{50} \fallingdotseq 0.1\%$) in the inhibition of NO production by macrophages [10].

In summary, we first demonstrated the anti-inflammatory effects of HSE by analyzing mediators in the two major pathways of inflammation (TNF-α-NO and COX II-PGE_2). Mechanistically, it was believed that HSE played a dual actions in the inflammatory process, dexamethasone- and indomethacin-like effects, implying that additional constituents inhibiting the COX II-PGE_2 pathway might be present in HSE, in addition to those acting on the TNF-α-NO pathway. Therefore, HSE could be a better drug candidate or adjunct than aqueous extracts for the relief of various types of inflammation that are responsive to corticosteroids or NSAID.

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