The Effect of Oak Wood Vinegar Extract on Blood Alcohol Concentration and Hangover Syndrome

Young In Choi[1], Jin Soo Kwon[2], Yoon Seok Song[3], and Sung Ho Wang[2]*

[1]Internal Medicine, Sincheon General Hospital., 109-4, Ganeung-dong, Uijeongbu, Gyeonggi-do 480-100, Korea

[2]Bio Oaky Corp., 11F il-sin B/D, 541, Dohwa-dong, Mapo-gu, Seoul 121-040, Korea

[3]Department of Chemical & Biological Engineering, Korea University, 1, 5-ga, Anam-dong, Sungbuk-ku, Seoul 136-701, Korea

Abstract – The study was conducted to determine whether oak wood vinegar extract influences blood alcohol concentration and hangover syndrome in healthy volunteers. 2% wood vinegar extract was effective to inhibit increase of blood alcohol concentration after alcohol intake and showed significantly different (P<0.1) compared to placebo. By result of questionnaire of volunteers, wood vinegar extract showed effects improving hangover syndrome. In comparative study about blood alcohol concentration and hangover syndrome of wood vinegar extract and other extract that hangover improvement effect was reported, average maximum blood alcohol concentration was lowered in those taking wood vinegar extract than those taking other extract. At drinking completion 210minutes (T210), blood alcohol concentration of those taking wood vinegar extract was the lowest by 0.063% compared with other extract but was not significantly different between in those taking wood vinegar extract and in those taking other extract. However, wood vinegar extract's experimental group was the highest by 0.462 in decrement rate of blood alcohol concentration and, when did P<0.1 by significance level, indicated difference that mean statistically compared to placebo group uniquely. At those taking wood vinegar extract, the improvement rate and the aggravation rate of hangover syndrome was each 87%, 2%. Thus it was concluded that wood vinegar extract showed excellent alcohol oxidation and was effective in hangover improvement.

Keywords ☐ wood vinegar extract, hangover syndrome, blood alcohol concentration, alcohol, alcohol oxidation

Korea, when compared to advanced nations, has a relatively greater drinking population. Due to its specific drinking culture where repeatedly drinking large quantities of ethanol (referred to as alcohol in the remainder of this work) is encouraged and, in a manner, coerced, many Koreans are subject to chronic exposition to alcohol. Chronic drinking of alcohol often results in pancreatitis, myocardial infarction, neuropathies, and tuberculosis, among other conditions; in extreme cases, life-threatening damage to the liver structure, its general function, or both, are possible (Lieber et al, 1986; 1992). Furthermore, excessive intake of alcohol can result in nausea, vomiting, dizziness, dehydration, sluggishness, headaches, muscle aches, and other physical conditions (hangovers) that interfere with

work efficiency, creating incalculable socioeconomic losses (Swift et al, 1998).

Alcohol is a CNS (Central Nervous System) suppressant (Kolb et al, 1982). Of the entire nervous system, the CNS is the most affected by alcohol. Hence, there is a direct relationship between the BAC and the effect of alcohol on the CNS.

Current trends on health care emphasize the prevention of the onset of diseases rather than curing a medical condition once it becomes apparent, which is important in of itself. One of the aspects of prevention is a focus on healthy lifestyle choices, such as the consumption of healthy foods, as opposed to past medical practices where a patient was given medication for treatment of a disease or condition due to an unhealthy lifestyle.

Burning oak wood under anaerobic conditions such as in a charcoal kiln will produce charcoal due to a process known as carbonization. Naturally cooling the smoke produced in the

*Corresponding author
Tel: 82-2-717-2021,   Fax: 82-2-717-2003
E-mail: webmaster@oaky.co.kr

carbonization process and liquefying it will result in an aqueous solution known as oak vinegar. The solution, after completing several stages of refinement, will result in a non-toxic, edible liquid called "oak vinegar essence": this liquid contains acetic acid, propionic acid, and other organic acids; phenol compounds; and minerals, including calcium, magnesium, and zinc, among others (Wang, 1999). The main ingredient of the oak vinegar is the acetic acid, which act as a starting material for the Krebs cycle, stimulating the body's metabolism. It also breaks down the body's wastes and other by products, and aids in the discharge of the wastes (Kerbs et al., 1948). It has also been revealed that oak vinegar essence will rapidly discharge acidic and toxic materials created by the consumption of alcohol, aiding in the rapid recuperation of alcohol-induced hangovers such as headaches, body fatigue, feelings of exhaustion, bloating, vomiting, etc (Choi, 1999). However, it is nearly impossible to find any clinical research indicating whether oak vinegar essence truly breaks down alcohol. A concerted clinical analysis is necessary to determine whether oak vinegar essence is a viable cure for the lingering effects of hangovers; to allow its precise and active utilization; and to prevent any false representations or exaggerated claims as to its effectiveness.

This paper studies the effects of oak vinegar extract ingestion on the increase of BAC levels, and the effects oak vinegar extract has on the clinical symptoms related to hangovers. Furthermore, the lowering of BAC levels and effects on hangovers of the oak vinegar extract were compared with other hangover treatment extracts, including rice germs, Korean raisins (fruit from Hovenia Dulcis var. Coreana) (An et al., 1999), and alder tree.

MATERIALS AND METHODS

Experimental Materials

Commercially available Korean raisins and alder tree bark were cleaned and prepared for sampling. One kilogram of each sample was placed in a flask attached with a reflux condenser, and distilled water, five times the weight of the samples, was added. The distilled water and samples were boiled for four hours at 100°C and samples were taken twice during the process. The resulting samples were filtered, condensed, and freeze-dried while still hot. The rice germ extract was obtained from Hyang Rim Corporation (Seoul, Korea) and the oak vinegar extract was obtained from Bio Oaky (Seoul, Korea).

Experimental Design

The experiments were used double-blind randomized cross-over study.

Volunteer Conditions

Healthy volunteers between the ages of nineteen and forty-five who indicated that they ordinarily consume alcohol in their clinical trial agreement and consent form.

Conditions for excluding volunteers

Pregnant or nursing women or those who are not using contraceptives or other forms of birth control were excluded. Exclusion was also extended to subjects who are currently taking ulcer medication or have actively used such medication within 6 months of the study; subjects who have hypertension, diabetes, and other medical conditions; and subjects who have in the past received surgery and medical aid due to pancreatitis, gout, and gastrointestinal surgery.

Monitoring of volunteers

Healthy volunteers were informed of the objectives and procedures of the research, and the volunteers were subjected to the experiments after 7 days of abstaining from alcohol.

Alcohol Type

The alcohol used in this experiment was Soju (JINRO Co., Ltd, alcohol content 23%, Seoul, Korea).

Experimental Procedure

1) The effects of oak vinegar extract on BAC levels and treatment of hangovers

Twenty-four male volunteers and five female healthy volunteers were selected, with their age distribution as shown in Table I. Volunteers were divided according to their weight and sex into four groups: Males over 70 kg, males under 70 kg, females over 50 kg, and females under 50 kg. The volunteers were asked to complete a survey, and were placed in order into group A, B, or C, and given a number. Group A was given a

Table I. Age distribution and sex of volunteers

Age	Male	Female	Total
20-24	0	1	1
25-29	9	3	12
30-34	7	0	7
35-39	3	0	3
Above 40	5	1	6
Total	24	5	29

placebo; Group B a 1% oak vinegar extract solution; and Group C a 2% oak vinegar extract solution. Blood samples were taken for all members of each group, and volunteers were asked to drink half a bottle of Soju (180ml, or 9gm of alcohol) in 30 minutes. The alcohol appetizer was a half-order of steak. A second blood sample was taken after the 30 minutes. Group A consumed 100ml of the placebo, and Groups B and C were given 1% and 2% diluted oak vinegar extract, respectively. This was followed by another 30 minutes where the subjects consumed another half-order of steak, and a third blood sample was taken after the 30 minutes were up. After the third blood sample was drawn, the subjects were given free-reign on alcohol and appetizer consumption. Subjects were called over the telephone and individually asked about their hangovers the next day.

2) Comparison of Blood Alcohol Levels and Hangover Symptoms for Oak Vinegar Extract and Other Hangover Remedies

Fifty volunteers between the ages of nineteen and thirty-nine were who were healthy and could drink one bottle of Soju were selected. The volunteers were divided into two groups based on the body weight of 70 kg, regardless of sex (28 of the volunteers were above 70 kg and 22 of the volunteers were below 70 kg). A lottery was used to further divide this group into five groups of ten people (A, B, C, D, E)(Table II). Group A was given a rice germ extract; Group B, Korean raisin extract; Group C, oak vinegar extract; Group D, a placebo and Group E, alder tree extract. The volunteer BAC levels were measured prior to their participation in the trials, and given solutions that combine 100 ml of distilled water with two grams of oak vine-

gar extract or other hangover remedies or the placebo. The volunteers were then asked to drink one bottle of Soju (360 ml) and 90g of pork over a period of 30 minutes. Blood samples were taken at 30, 90, 150, and 210 minutes after final consumption of alcohol, and another 100 ml of their respective trial solutions were given to the volunteers after taking blood samples at the 90 and 210 minute intervals. The volunteers were given free-reign on the consumption of alcohol after the 210 minute interval. Subjects were called over the telephone and individually asked about their hangovers the next day.

Analysis of Samples

All blood samples were collected in vacuum containers that contained EDTA (Ethylenediaminetetraacetic acid) and stored under refrigeration until the end of the trials. After the trials, a centrifuge was used to separate the plasma from the blood at 3,000 rpm in 20 minutes. The BAC levels were analyzed using the alcohol dehydrogenase using an analysis kit by Roche (Switzerland) and a biochemical analyzer (Cobra Integra, Switzerland) was used for analysis.

Surveys

Surveys were taken twice on the subject of hangover symptoms. Volunteers were asked about their usual hangover symptoms. On the morning of the day after the trials, volunteers were asked to complete a survey on their hangover symptoms. The second survey, in order to minimize recollection of answers from the first survey, used the same survey questions but the questions were placed in different sequences and a scoring system was used.

Table II. General characteristics of volunteers

Volunteer	Group A		Group B		Group C		Group D		Group E	
	Age	Weight	Age	Weight	Age	Weight	Age	Weight	Age	Weight
1	27	48	19	66	28	46	26	63	19	62
2	26	54	24	67	22	67	19	68	31	78
3	20	68	23	63	29	62	24	63	31	55
4	19	60	27	47	24	65	19	56	23	54
5	22	68	33	82	28	110	33	76	31	100
6	28	70	21	72	31	75	19	84	31	78
7	31	73	21	78	32	85	19	90	29	87
8	39	101	31	80	23	74	19	72	25	69
9	24	84	29	75	39	77	36	71	24	72
10	22	80	24	77	24	61	32	80	24	74
mean±S.D	25.8±5.9	70.6±15.3	25.2±4.6	70.7±10.5	28±5.2	72.2±17.1	24.6±6.8	72.3±10.4	26.8±4.3	72.9±14.1

The values are mean±S.D. of 10 replications

Statistical Analysis

The statistical analysis of the collected data was focused on whether differences existed between ingesting hangover remedies and not ingesting them. The non-parametric Mann-Whitney test was used for statistical analysis, and only those results where the p-value was lower than 0.1 were deemed statistically significant.

Emergency Response

An expert (or major) in the anesthesiology department and an ambulance were always present until the termination of the trials to provide emergency medical response in the event of problems during the trials.

RESULTS

The effects of oak vinegar extract on blood alcohol concentrations

Figure 1 and Table III show, respectively, the average change in volunteers BAC levels; average rise in participant BAC levels and the rate of increase of average BAC level. The group
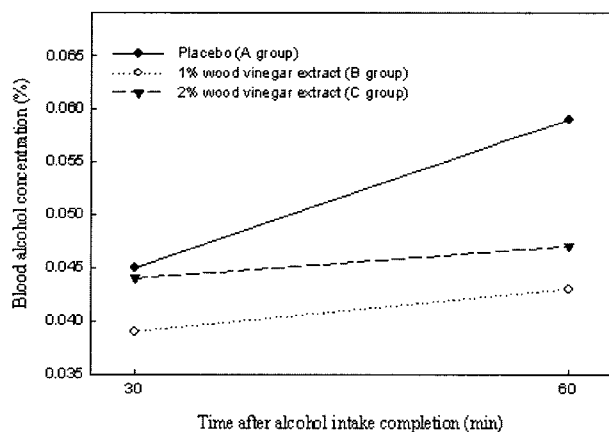

Fig. 1. Change of blood alcohol concentration after alcohol intake completion on effects of oak vinegar extract.

Table III. Comparison of blood alcohol concentration to be increased

Experimental groups	T(60-30)	T(60-30)/T30[1]
Placebo (A group)	0.014±0.01	0.367±0.31
1% wood vinegar extract (B group)	0.004±0.01	0.170±0.33
2% wood vinegar extract (C group)	0.003±0.01	0.105±0.27

[1]The rate of increase of blood alcohol concentration.
The values are mean±S.D. of 10 replications.

that consumed placebo showed a marked increase in BAC levels at 60 minutes when compared to BAC at 30 minutes. The placebo group (group A) showed BAC levels of 0.045% and 0.059% for T30 (30 minutes after consuming alcohol) and for T60(60 minutes after consuming alcohol), respectively. Group B (1% oak vinegar extract solution) and group C (2% oak vinegar extract solution) also showed increased BAC levels at T60 than at T30, but BAC levels were lower than those of the group A. The group that took the 1% oak vinegar extract solution showed average BAC levels of 0.039% and 0.043% at T30 and T60, respectively. The group that took the 2% oak vinegar extract solution showed average BAC levels of 0.044% and 0.047% at T30 and T60, respectively.

As seen in table III the increase in BAC levels (the difference between T(60) and T(30)) of the groups that ingested oak vinegar essence were much lower when compared to those on the placebo. The increase in BAC levels for the placebo group was 0.014%, while those for the 1% and 2% oak vinegar extract solution groups are 0.004% and 0.003%, respectively. Assigning the increase in BAC levels for the placebo group a score of 100, the 1% and 2% oak vinegar extract solution groups showed a decrease in their BAC level increase to 71.4% and 78.6%. While BAC levels at T30 and T60 were lowest for the 1 % oak vinegar extract solution, the 2% oak vinegar extract solution was more effective at preventing increases in BAC levels. Statistical analysis was used to find any differences in the degree of BAC increase between the placebo group and the oak vinegar extract groups. The differences in increase of BAC levels between the oak vinegar extract groups and the placebo group was shown to be statistically significant (p<0.1). In light of such results, it is believed that the 1% and 2% oak vinegar extract solutions have shown to be effective in preventing the increase of BAC levels, and that the 2% solution is better than the 1% solution in preventing the increase of BAC levels.

## The effect of the oak vinegar extract as hangover remedy

It can be seen from Table IV that five of the twenty-nine volunteers didn't show the usual hangover symptoms. The remaining twenty-four claimed the usual hangover symptoms, with sleeping late, headaches, and gastrointestinal discomfort (dry-heaving, heartburn, vomiting, diarrhea, etc) as the main complaints. The ingestion of oak vinegar extract did not have a marked effect on oversleeping late; however, it did show improvement in headache, gastrointestinal trouble, and memory impediment.

Table IV. Hangover syndrome of wood vinegar extract

Hangover syndrome	Ordinary times	After wood vinegar extract intake		
		Negative	Same	Positive
No	5			
Oversleeping	13	0	11	2
Headache	11	1	1	9
Gastrointestinal trouble	14	1	3	10
Arthralgia	1	0	0	1
Memory impediment	6	0	0	6

Changes of blood alcohol concentrations by oak vinegar extract and other hangover remedies

The reduction in BAC levels for the placebo group, the oak vinegar extract group, and other hangover remedies group were compared. Group A ingested rice germ extract; Group B, Korean raisin extract; Group C, oak vinegar extract; Group D, placebo; and Group E, alder tree extract. Analysis of blood samples taken prior to the trial confirmed that volunteers' blood were free of alcohol. After consuming alcohol, the placebo group (Group D) showed an individual with the highest BAC (Tmax) of 0.03%. This value is extremely low when compared to the BAC levels of the other volunteers, and was excluded from the statistical analysis. Figure 2 shows the changes in average BAC levels for each group at various periods. The highest average BAC level for Group B, C, and E (Korean raisin, oak vinegar, and alder tree) were at T30, while the highest average BAC level of group A and D (rice germ and placebo) were at T90. The BAC levels for all groups slowly decreased after reaching their respective peaks as seen in Figure 2. Group D (placebo) had the lowest average BAC level at T30, with BAC levels of 0.097%. However, it had the highest average BAC level at T210 when compared to other groups, with BAC
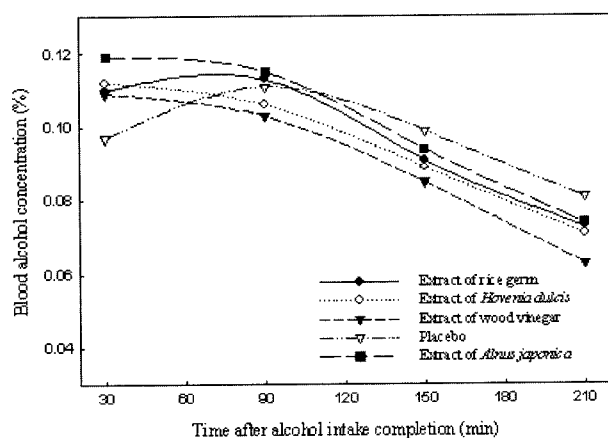
Fig. 2. Change of blood alcohol concentration after alcohol intake completion by oak vinegar extract and other hangover remedies.

Table V. Comparison of maximum blood alcohol concentration and the rate of decrease of blood alcohol concentration

Experimental groups	Tmax	(Tmax-T210)/Tmax
Extract of rice germ (A group)	0.116±0.032	0.395±0.176
Extract of *Hovenia dulsis* (B gorup)	0.116±0.034	0.390±0.113
Extract of wood vinegar (C group)	0.111±0.035	0.462±0.180
Placebo (D group)	0.120±0.024	0.318±0.159
Extract of *Alnus japonica* (E group)	0.125±0.021	0.414±0.139

The values are mean±S.D. of 10 replications.

levels of 0.081%. Group C (oak vinegar) had the lowest average BAC level of all groups at T210, with BAC level of 0.063%. Table V show the maximum BAC levels and the reduction ratio of BAC levels in each group. Group A, B, and C (rice germ, Korean raisin, and oak vinegar) had the highest average BAC levels (Tmax) of 0.116%, 0.116%, and 0.111%, respectively. The Tmax for Group E (alder tree), however, was at 0.125%, which is higher than the 0.120% of Group D (placebo). The reduction ratio ((Tmax-T210)/Tmax) of average BAC levels for Groups A, B, C, D, and E are 0.395, 0.390, 0.462, 0.318, and 0.414, respectively. Statistical analysis was performed to find the differences, if any, of the reduction ratio of average BAC level between the placebo group and the other trial groups. When deeming those results with $p<0.1$ as statistically significant, Group C (oak vinegar) showed a significant the reduction ratio of average BAC level with $p=0.095$. Groups A, B, and E, (rice germ, Korean raisin, and alder tree) while seemingly showing the reduction ratio of average BAC levels had p-values of $P=0.315$, $P=0.243$, and $P=0.156$, respectively, which were not statistically relevant. Hence, it was revealed that the oak vinegar extract was effective in preventing the increase of BAC levels.

Comparison of hangover symptoms by oak vinegar extract and other hangover remedies

Of the fifty volunteers, a total of thirty-two answered the survey (Group A: 5 people, Group B: 7 people, Group C: 7 people, Group D: 6 people, and Group E: 7 people). Table VI shows the results of the survey for each group. In order to assess the results, surveys were classified as either positive or negative. The "positive" classification refers to the lack of the usual hangovers, while the "negative" classification refers to instances when hangover symptoms other than those usually experienced

Table VI. Comparison of hangover syndrome

Hangover syndrome	Experimental groups	Ordinary times Yes	After experiment 0	below 0.5	above 0.5	Ordinary times No	After experiment 0	below 0.5	above 0.5
Headache	rice germ	1	0	1		4	3	1	
	Hovenia dulsis	1	1	0	0	6	4	2	
	wood vinegar	2	2			5	5		
	Placebo	2	1	1		4	1	3	
	Alnus japonica	1	0	1		6	4	2	
Dizziness	rice germ	0	0			5	2	3	
	Hovenia dulsis	2	2			5	4	1	
	wood vinegar	1	0			6	6		
	Placebo					6	0	5	1
	Alnus japonica	0	0	0		7	4	3	
Vomiting	rice germ	0	0			5	3	2	
	Hovenia dulsis	2	1	1		5	4	1	
	wood vinegar	0	0			7	7		
	Placebo					6	3	3	
	Alnus japonica	0	0	0		7	5	2	
Stomachache	rice germ	0	0			5	3	2	
	Hovenia dulsis	3	2	1		4	4		
	wood vinegar	3	2	1		4	4		
	Placebo	1	0	1		5	2	3	
	Alnus japonica	1	0	1		6	3	3	
Diarrhea	rice germ	1	1			4	1	3	
	Hovenia dulsis	2	1	1		5	4	1	
	wood vinegar	3	2	1		4	4		
	Placebo	2	1	1		4	2	2	
	Alnus japonica	3	2	0	1	4	2	1	1
Thirst	rice germ	2	0	2		3	0	2	1
	Hovenia dulsis	3	1	2		4	3		1
	wood vinegar	3	3	0		4	3	1	
	Placebo	3	0	3		3	1	2	
	Alnus japonica	4	0	3	1	3	0	3	
Arthralgia	rice germ	1	0	1		4	2	2	
	Hovenia dulsis	0				7	6	1	
	wood vinegar	0	0	0		7	7		
	Placebo	1	0	0	1	5	3	2	
	Alnus japonica	1	0	1		6	6	0	
No memory	rice germ	2	2			3	3		
	Hovenia dulsis	1	1			6	6		
	wood vinegar	3	3	0		4	4	0	
	Placebo	2	2	0		4	4	0	
	Alnus japonica	2	2	0		5	5	0	

by the volunteer were present. Table VII shows the positive ratio ((positive symptoms/usual symptoms)*100) and the negative ratio ((negative symptoms/unusual symptoms)*100) for each group. The positive ratio for Group E (alder tree) was 33% lower than group D (placebo), while Group C (oak vinegar) was higher than Group D (placebo) by 87%. Groups A (rice germ) and B (Korean raisin) had higher positive ratios than Group D (placebo) by 43% and 64%, respectively. The nega-

tive ratios for all non-control groups were lower than Group D (placebo), with group C being the lowest, at 2%. Group C (oak vinegar) showed the best results in helping the symptoms of hangovers.

DISCUSSION

As seen in the above results-in the prevention of BAC levels

Table VII. Comparison of improvement rate and aggravation rate of hangover syndrome

Groups	Improvement rate(%)	Aggravation rate(%)
Extract of rice germ (A group)	43	48
Extract of *Hovenia dulsis* (B group)	64	16
Wood vinegar extract (C group)	87	2
Placebo (D group)	36	56
Extract of *Alnus japonica* (E group)	33	34

increase by oak vinegar extract, the BAC reduction effect due to oak vinegar extract and other hangover remedies, and in the comparison in easing hangover symptoms-ingestion of oak vinegar extract aids in breaking down alcohol and can potentially be used as an effective means for rapidly ridding of hangover symptoms.

Cross-testing is frequent in BAC analyses. Such testing is done to compensate for any effects an individual BAC reading may have on the results. Blood alcohol concentrations tend to be affected by a variety of factors, such as the weight of the drinker, distribution of body fat, whether a person had a meal before drinking, whether a person is a regular drinker, etc. Cross-testing was not performed in this research. However, there were no statistical differences in weight between all groups; all volunteers started the tests on an empty stomach; and only people who usually are able to at least drink one bottle of Soju in thirty minutes were selected for the trials. Under the circumstances, it would not be inaccurate to point out that any effects not corrected via cross-testing would be minimal, and that these could be ignored.

While it is believed that the BAC level distribution vs. time would follow a normal or t distribution, there is no way of confirming such a belief. The small sample size and the use of non-parametric statistical analysis ultimately resulted in a low return of significant results. It is believed that using at least thirty volunteers in each test group, and assuming a normal distribution of the results, will lead to more significant conclusions.

Not all hangover symptoms after excessive drinking are due to alcohol. Naturally, alcohol does have a direct effect on the nerve cells; however, hangover symptoms persist even after BAC levels have decreased significantly, and it is difficult to say that all the hangover symptoms are solely the effect of alcohol. While it is a contentious issue, there are some that argue that acetaldehyde, a metabolic byproduct of alcohol, is the main reason for the hangover symptoms (Paek, 1994; Kim, 1999). This study did not measure acetaldehyde levels. It is recom-

mended that future research also measure the concentration of acetaldehyde in the blood for a clearer picture and more accurate conclusion to the research.

It is not conclusive whether the reduction of hangover symptoms that the volunteers experienced after drinking the alleged hangover remedies was due to the reduction of BAC. Therefore, it is necessary to conduct hangover symptom surveys on an individual-by-individual basis to arrive at an accurate conclusion. Unfortunately, such surveys can only render qualitative data that is subject to the feelings and experiences of each volunteer, and affected by uncontrollable factors such as a person's way of thinking. Due to such obstacles, data collected via surveys can fail in their objectivity. It is believed to be appropriate, however, to use the results from surveys, and compare them with the results from BAC level measurements to assess the effectiveness of the hangover remedies.

ACKNOWLEDGMENTS

REFERENCES

An, S. W. and Kim, Y. G. (1999). Comparison of Hepatic Detoxification activity and reducing Serum Alcohol concnetration of *Hovenia dulsis* THUNB and *Alnus japonica* Steud. *Korean J. Medicinal Crop Sci.* **7**, 263-268.

Choi, Y. I. (1999). Plant vinegar saves human life. Sung-Ha, Seoul, Korea

Kerbs, H. A. and Eggleston, L. V. (1948). Observations on transimination in liver homogenates. *Biochimica et biophysica acta.* **2**, 319-328.

Kim, C. I. (1999). Cause and effect of hangover. *Food Ind. Nur.* **4**, 26-30.

kolb, E. and Brodie, A. (1982). Modern clinical psychiatry, W.B. Saunders company., New York.

Lieber, C. S., Garro, A., Leo, M. A., Mak, K. M. and Wornor, T. (1986). Alcohol and cancer. *Hepatology.* **6**, 1005-1019.

Lieber, C. S. and Leo, M. A. (1992). Alcohol and liver. In Medical and nutritional complications of alcoholims: mechanism and management (Lieber, C. S, Ed.), pp 185. Plenum Medical Book Co, New York.

Paek, S. C. (1994). Ethanol oxidation is accelerated by augmentation of malate-aspartate shuttle with aspartate. *Korean J. Biochem.* **25**, 137-143.

Swift, R. and Davidson, D. (1998). Alcohol hangover, mechanism and mediators. *Alcohol Health Res World.* **22**, 54-60.

Wang, S. H. (1999) Removal method of harmful ingredient that is included to wood vinegar. Korean Industrial Property, patent number 10-0212472.