Effect of Palatinose Administration on α1 Brain Waves in Human Volunteers

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The effect of palatinose intake on α1 brain wave generation was studied by human volunteer test. Twelve healthy volunteers were administered 40 g of palatinose or sucrose, and electroencephalography (EEG) was taken before and at 150 min after administration. The area of α1 wave generation on topographs increased after administration of either sugar, but there was a significant difference in the intensity between the palatinose and sucrose groups. Ten volunteers were administered 100 mg of theanine, which has a relaxing effect, in combination with 17.5 g of palatinose (α1-P group), and EEGs were recorded before, at 60 and 150 min after administration. Though the area of generated α1 brain wave in the topographs increased in both groups (α1-P and 17.5 g palatinose groups) after administration, the patterns of their increase differed. Nine volunteers were administered 5 g of palatinose, and EEGs were recorded before and at 150 min after the administration. The area of α1 wave generation increased slightly but less than that in 40 g palatinose group. The above results suggested that palatinose enhances generation of α waves and that its effect might be maintained longer than that of sucrose.

Keywords: palatinose, brain waves, α1 waves

Palatinose (1,1'-o-d-glucopyranosyl-o-d-fructose, isomaltuloose) is used as an ingredient for functional foods because of its physiological characteristics; for example, it is non-cariogenic (Minnari et al., 1990; Ooshima et al., 1983a, b), causes a gradual increase in blood glucose level and a slight secretion of insulin (Kawin et al., 1989). Palatinose is a structural isomer of sucrose and a disaccharide composed of glucose and fructose with an α-1,6 bond. Sucrose and glucose are known to change into blood glucose after ingestion and are utilized as the energy source for the brain. Recent studies have shown that the mental state (emotion, mood) in human is strongly related to the blood glucose level and glucose supply to the brain (Benton, 1998; Keel et al., 1982; Martin & Benton, 1999). Palatinose, which differs from sucrose in the time-course change of blood glucose level, is believed to have a different effect on the mental state of humans. This was the reason the effect of palatinose administration on mental concentration was investigated by Kashiwara et al. (2003).

In today’s stressful society there are various products promoting relaxation, and there are several ongoing studies about the relaxing effects of chemicals that directly appeal to the five senses: visual, images, music, flavor and taste (Kawano, 2000; Kawaki et al., 1998; Nagai, 2002). Various flavoring and seasoning ingredients are used in commercial foods claiming to have a relaxing effect, however, these sometimes do not meet people’s preferences. Thus, there are studies focusing on substances such as theanine contained in green tea, which affect the release or decline of neurotransmitters in the brain, even when taken in a concentration which is not high enough to impart taste (Huncia et al., 1999; Kobayashi et al., 1998; Yokogoshi et al., 1998). With such a substance, the relaxing effect is perceived not during its ingestion but after a certain metabolic period has elapsed. It is likely that substances such as sugars, which are consumed by the brain cells, may affect emotion during their physiological process even after being absorbed and metabolized in the organs.

In this study, EEG analysis was used as a main index to estimate emotion including relaxation in human. EEGs are classified by their frequency into δ, θ, α and β waves. It is said that δ waves (0.5–3 Hz) are associated with deep sleep, θ waves (4–7 Hz) appear as people fall into drowsiness, α waves (8–13 Hz) appear in a relaxed state, and β waves (14 Hz and above) are associated with an excited state, and that α waves are divided into α1 waves (10 Hz and below) and α2 waves (10 Hz and above). In the resting and relaxing state the α1 wave tends to increase, and the α2 wave and the β wave tend to generate alternately in the concentrative and thinking states. In other words, low frequency EEGs tend to appear while the brain is not active as in deep sleep, and high frequency waves appear while the brain is excited and active as in learning. Various studies on the relationship between a relaxing effect and α wave generation have shown that α waves usually show quantitative change both in the generated site in the brain and in frequency when people feel relaxed. These quantitative changes sometimes vary according to the relaxing therapy and intake of foods (Kawano, 2000). Machi et al. (2001) and Chen et al. (2000) have studied how Qigong therapy or the use of different cathode ray tubes (CRT) affected the generation of α1 wave, and reported on the relationship of changes in heart rate, body temperature, skin resistance and EEG and a relaxed state. They confirmed in these studies that the area of α1 wave generation increased first in the occipital region and then toward the frontal region on the topographic map, and the power of the α1 wave increased in a relaxed state, which suggested that the area of α1...
wave generation could serve as a parameter of a relaxation effect. In this study, we investigated what role palatineus, a sugar which has a remarkable effect on the slow raising and maintain- ing of the blood glucose level, plays in the generation of α brain waves in human.

Materials and Methods
Materials
Crystalline palatineus-IC was used as palatineus and granulated sugar CM as sucrose, both of them pro- duced by Shisei Matsui Sugar Co., Ltd. (Tokyo). For theanine, Santheinatm II-theanine content 98.9% produced by Taito Kagakudô Co., Ltd. (Yokohama), was used.

Subjects
Eighteen healthy volunteers (21–40 years of age, 16 men and 2 women) participated in this study. The volunteers underwent electromyography prior to their participation in the study, and were confirmed not to have an abnormal EEG. Since the test substance was a sugar, the volunteers were asked not to take any food or drug, except water, for 12 h preceding the test, to exclude the influence of other factors on changes in blood glucose and EEGs. As this study was conducted in accordance with the code of ethics of the World Medical Association (Hol- sinki) Declaration of 1964, as revised in 1989, the content and methods of the study were fully explained to the volunteers, and their informed consent was obtained in writing.

Design and procedure
In Experiment 1, the effects of palatineus and sucrose were compared. First, EEGs were recorded for 5 min in 12 volunteers (21–40 years of age, 11 men, 1 woman) with their eyes closed, and the data obtained were used as the initial values. Next, the volunteers were admin- istered 40 g of palatineus or sucrose dissolved in water (190 mL), then after a 130-min rest they were asked to work using a word processor for 20 min, and subsequently to rest with their eyes closed for 5 min to record EEGs. Each volunteer was subjected to the palatineus and sucrose tests on different days.

In Experiment 2, the effect of palatineus alone was compared with the effect of palatineus combined with theanine. In 10 of the volunteers (21–40 years of age, 8 men, 2 women), EEGs were recorded for 5 min while they had their eyes closed and resting, and the data obtained were used as the initial values. Next, the volunteers were administered an aqueous solution containing palatineus alone or an aqueous solution containing palatineus and theanine (380 mL), and EEGs were recorded at 60 min and 150 min after administration while resting with their eyes closed.

Results
In Experiment 1, the palatineus dose was reduced, and the results were compared with those of Experiment 1. First, EEGs were recorded in 12 volunteers (21–33 years of age, 8 men, 1 wom- an) as already described. Next, the volunteers were administered 5 g of palatineus in water (190 mL), then they were asked to use a word processor for 20 min from 130 min after the administra- tion, and subsequently to rest for 5 min with their eyes closed to record EEGs. The dose of 5 g is thought to correspond to the amount of sugar generally used for a cup of coffee or black tea.

Measurement and analysis of EEGs
EEGs were recorded with a digital electromyograph (SYNAPFEE5521, NEC San-ei Instruments, Ltd., Tokyo), using the referential derivatath method (unipolar recording) and 19 channels, with the left and right earlobe electrodes as reference electrodes according to the international 10–20 electrode system. Sampling frequency was 200 Hz. Of the recorded EEGs, the α wave zone (9–10 Hz) was decomposed by fast Fourier transform (FFT) at intervals of 5.12 s, then EEG mapping was performed for 5 min with 2.56 s as a unit, and EEG topographs were analyzed using ATALAS (Kissei Corp., Tokyo).

In the analysis of EEG topographs, the area in which α waves above a certain potential appeared was calculated from each topograph obtained in the course of every 5 min, and the mean α generation area with the subject resting with closed eyes was determined by averaging these areas. Using the initial mean area of α wave generation, which represented the ordi- nary state as 1, the relative value of the mean area of α genera- tion after the administration was computed. Since the initial EEGs as the basic intensities were measured each time and for each subject, differences in physical conditions and the date might be negligible. It is well known that α waves appear in the occipital region while the subject rests with his/her eyes closed. Workload on the subject changes not only the power of α wave generation but also the area of an α wave generation, and the re- moval of the workload also changes these values.

Results and Discussion
Comparison of α waves after palatineus and sucrose intake
In Experiment 1, Figure 1 shows the (first 30 s) of the time-course topograph as the initial intensity, and of the time- course topograph obtained 150 min after the administration of palatineus in one subject. The deep red part represents the area of α waves of high power, which was small in the initial topograph and enlarged in the post-dose topograph. Figure 2 shows the rela-
Fig. 1. Typical example of topography of α waves. (A) is the first 30 s of the time-course topographs for the initial intensity; and (B) is 150 min after palatine administration.

![Topography of α waves before and after palatine administration](image)

Fig. 2. Comparison of the α wave generation after sucrose and palatine intake. The values are the relative values of the mean area of α wave generation 150 min after the sugar administration of 40 g, and are the ratio of the initial mean area. The values are the mean±SEM of 12 subjects. *p<0.01, compared with values of the sucrose administration group.

![Comparison of α wave generation](chart)

palatine significantly increased the generation of α waves as compared with sucrose at 150 min after the administration when the glucose supply to the brain was already past the peak level, this suggests that palatine also plays a role in maintaining a relaxing effect in addition to supplying glucose to the brain.

Combined effect of palatine and thiamine (Experiment 2) Figure 3 shows the relative values of the α wave generated area at 60 min and 150 min after the administration calculated from the results of brain wave measurement in Experiment 2. The initial topographic area of α wave generation was defined as 1 in calculating relative value. For each subject, the post-dose change of area from the initial value was analyzed by two-way analysis of variance with repeated-measures, which did not show a significant difference regardless of the method of administration however, the relative value in the combined administration group was higher than in the palatine administration group. A significant difference was detected in post-dose change of area (p<0.01) by
either administration, which confirmed that either was effective in increasing the area of α wave generation. Comparison between at 60 min and 150 min showed the relative values of the α wave generation area to be the same level, which suggests that palatineous could sustain the glucose supply to brain cells. It takes 60 min or slightly less for the glucose level to peak after the administration of a sugar, so that the supply of sugar to the brain at 60 min must be greater than at 150 min after the administration. From the values at 60 min and at 150 min after the administration, therefore, the course of change between those time points can be estimated. Since theanine was reported to reach the brain about 30 min after the administration in a rat experiment and administration of 50 mg or more theanine significantly enhanced the α waves power (Kobayashi et al., 1998), it seemed likely that the administration of 100 mg theanine in the present study would produce a sufficient α wave enhancing effect after 60 min, and that this effect would decrease thereafter. Accordingly, it was inferred that the greater increase in the area of α wave generation in the combined palatineous and theanine group vs the palatineous alone group was attributable to the theanine, and the decrease in the area of α wave generation at 60 min to 150 min after the administration in the combined administration group was due to a decrease in the effect of theanine.

Administration of 5 g palatineous (Experiment 1) Figure 4 shows the relative values for the area of α wave generation 150 min after the administration of 5 g palatineous, as compared with those after the administration of 40 g palatineous in Experiment 1. After the administration of 5 g palatineous, the area of α wave generation increased as compared with the initial value. Comparison of the area of α wave generation 150 min after the administration between 5 g and 40 g doses by t-test revealed no significant difference. However, the small dose of 5 g palatineous could increase the α wave generation area. The area of α wave generation at 150 min after the administration of 5 g palatineous was larger than that after the administration of 17.1 g palatineous in Experiment 2. This can be explained by the fact that α wave generation was more frequent with the workload than without work load, and volunteers did not get a workload in Experiment 2.

From the present study, the administration of palatineous was confirmed to influence the generation of α wave activity and sustained the effect as well as the effect on mental concentration (Kashimura et al., 2003). Although it is not reasonable to conclude that palatineous has a relaxing effect based only on the record of EEGs and calculations of the increase in the area of high-power α wave generation on the topographic map, the present approach may provide an index of the relaxing effect. We already knew that palatineous does not increase blood glucose level immediately but sustains a relatively slow increase in this level. We believe that this sustenance of blood glucose level relates to the sustainment of α wave generation effect because of the slower glucose supply to brain cells than in the case of sucrose administration. It is under consideration to measure time-course changes in the glucose supply to the brain after palatineous administration as well as changes in the concentrations of neurotransmitters in the brain to determine the effect and action mechanisms of palatineous on the brain.

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