Inert Gas Packaging of Tea

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As a method of keeping the quality of packed foods from changing, replacement of the head space gas in a package by an inert gas is widely utilized for dry foods. This method of packaging is very effective in case some oxidation-prone ingredients are contained in the foods, especially when the head space is large, or the bulk density is small.

Inert gas packaging is remarkably effective in case of tea for keeping the aroma, taste and color of liquor, and for preventing oxidation of ascorbic acid, because tea contains catechins, factors to produce aroma and astringent taste, and ascorbic acid, a hygienic factor, all of which are oxidation-prone ingredients greatly influencing its quality, and in addition, the head space is large. Therefore, inert gas packaging is now widely used for tea packaging, chiefly for green tea of high quality.

Materials for packaging

It is a matter, of course, that gas impermeability is the most important condition for the materials of inert gas packaging. In case of tea packaging, metallic cans are mainly used at present. Although the quality of cans is not the problem, they are too expensive and therefore plastic films have come to be used for packaging materials.

Some plastic films are excellent in gas impermeability, but none is found to have complete properties for a gas barrier when used alone. Some of the laminated films with aluminum foil, however, are nearly complete in gas impermeability, and this kind of materials will probably become the chief materials for packaging in future to replace metallic cans.

Table 1 shows the results[1] of a survey on the time variation of oxygen percentage of the head space gas in nitrogen gas packaging in case of flexible packaging. As indicated in this table, almost no changes are seen in the oxygen content in case of No. 3, the material using aluminum foil, in lamination. Therefore, it is considered to be sufficiently usable.

It must be noticed here that the aluminum foil of about 0.012 mm. thick has moisture permeability of 0.6~5.0 g/m^2/24 hrs.,[2] and

Table 1. Oxygen per cent of head space gas

Film No.	Storage Time		
	1 week	2 weeks	3 weeks
1	19.7 %	20.6 %	23.9 %
2	4.4	15.9	19.8
3	2.1	1.0	2.2

Score is average of three replications. Original Oxygen percentage is 2.5% (measured by gaschromatography)

Combination of films are as follows:

No. 1....Paper (65 g/m^2) · Polyvinylidene chloride coating (5 times 34 g/m^2).

No. 2....Cellophane (300 #) · Polyethylene (0.015 mm) · Paper (?) · Polyethylene (0.02 mm) · Polyvinylidene chloride coating (?)

No. 3....Cellophane (0.022 mm) · Polyethylene (0.03 mm) · Aluminum foil (0.012 mm) · Polyethylene (0.045 mm).

there must be a considerable number of pinholes, so its gas impermeability is not so good when it is used alone.

In spite of that, aluminum foil can have a high gas impermeability when it is coated with laminated plastics. Plastic films alone have also little gas impermeability as clearly shown by Nos. 1 and 2 in Table 1.

In addition to the gas barrier properties mentioned above, film packagings have their respective properties such as heat sealability, printability, moisture permeability and physical strength. By combining these properties properly, we can obtain excellent materials for packaging.[3]

Among the laminated materials which are usable for inert gas packaging within the range of our experiments, a combination of polypropylene (or cellophane), polyethylene, aluminum foil and polyethylene are recognized to be the most simple combinated materials and to have properties almost satisfactory for various requirements. The aluminum foil in the above stated combination is 0.007 mm thick and has shown satisfactory gas impermeability.

Method of gas replacement

In the gas replacement of small-sized packages, a method of evacuating air with vacuum to be replaced by an inert gas is chiefly employed at present. In this method, the replacement percentage is naturally different according to the vacuum rate in evacuating air.

Even when nitrogen gas with a high purity of 99.9% is replaced by making the vacuum rate of the vacuum box about 10 mm Hg, oxygen is still detected to be about 2 per cent. In case a higher percentage of gas replacement is required, it is better to use a method of repeating the work of evacuation and gas replacement than to make vacuum rate higher.

In case of large-sized packages, the method of evacuating air with vacuum is inconvenient because a large vacuum box must be prepared. Consequently, a method of injecting an inert gas is being studied.[4] By making use of this method, an experiment was made on tea, and its results indicate that it is impossible to do gas replacement sufficiently in short hours, and an increase of oxygen is detected in the head space gas 2 to 3 days after the gas is replaced.

Such events are also seen in case of powder dry milk, and it is believed to be due to the gas contained in the granules which remains unreplaced and is gradually diffused.[4] It can be also considered in case of tea that some part of the space within the curled tea leaves is left without gas replacement. It is necessary, therefore, to repeat the work of gas replacement again several days after.

In addition to the methods described above, a method of filling up and packaging in a streaming of inert gas has been studied for flexible packaging.[3]

Effect of gas packaging

The quality of tea is decided by an organoleptic test on five items, color and style which can be visually felt with non-infused tea, and aroma, taste and liquor. Among these five items, all except style are usually changed in quality and deteriorated during storage.

The most important factor for changing the quality of tea is oxidation by the oxygen in the air during storage, and it is clear that the moisture content and the storing temperature have a great influence upon oxidation speed. The oxygen content in the head space gas also has a considerable effect on oxidation speed.

According to the result of an experiment on the effect of these storing conditions upon change of quality, which was carried out under

Table 2. Factors and levels

Factors	Levels			
	1	2	3	4
Moisture content (W) %	3.2	6.7		
Storing temp. (T) °C	5	25		
Residual Oxygen (O) %	1.3	5.2	9.4	21.0
Storing time (M) month	2	4		
Blocks (B)	1	2	3	4

Table 3. Table of L_{32} Orthogonal arrays

Array No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Array label	a	b	a b	c	a c	b c	a b c e	d	a d	b d	a b d	c d	a c d	b c d	a b c d	e
Factors	B^1	B^2	B^3	T	O^1 W	O^2 M	e	O^3	T W	e	e	T O^1	W	O^3 M	e	O^2

Array No.	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Array label	a e	b e	a b e	c e	a c e	b c e	a b c	d e	a d e	b d e	a b d e	c d e	a c d e	b c d e	a b c d
Factors	W T O^1	T M	e	T O^2	O^3 W	M	e	O^1	W T O^2	e	W M	O^3 T	W O^2	O^1 M	e

Table 4. Scale categories assigned in this test

Score	Item
7	Moderately well
6	Slightly well
5	Same with standard
4	Slightly poor
3	Poor
2	Very poor
1	Extremely poor

Standard Samples are stored at temp. of −20°C and packaged in nitrogen atmosphere with 1.3% oxygen during the experiment period.

the program shown in Tables 2, 3, and 4,[5] the effect of temperature and moisture content covers all the items, color, aroma, liquor, taste and ascorbic acid content, and the effect of oxygen content is seen on the items except color, as shown by the analysis of variance in Table 5.

When an analysis is made on the above result from the viewpoint of the effect of oxygen content in the head space gas, an interaction is recognized between storing temperature and oxygen content regarding the liquor. When a study is further made on the changes of reductive ascorbic acid which shows oxidation phenomena most clearly, there is seen an interaction between two factors, the storing temperature and moisture content, and the oxygen content, and at the same time an interaction between the three factors mentioned above is also recognized.

A further study on the above result indicates, as given in Fig. 1, that there is no difference in effect of the storing temperature level and degree of the moisture content within the ranges of 5°C∼25°C in storing temperature and 3.2%∼6.7% in moisture content when the oxygen content in the head space gas is about 1%, and when oxygen content has become about 5%, a large effect of the moisture and the temperature can be detected. It is also recognized that complete preservation of quality is difficult when the oxygen content grows more than 10% even in low temperature and low moisture.

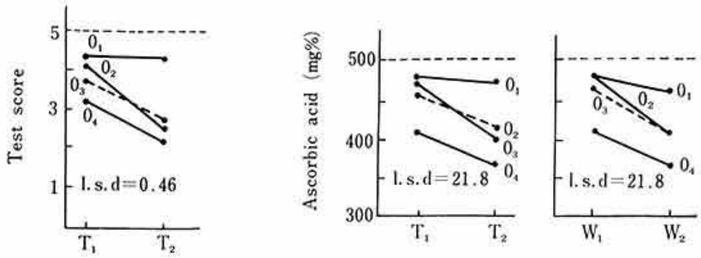
As already described, it is clear that a high efficiency in keeping the quality of tea can be obtained by replacing the oxygen in the head space gas with an inert gas as one of the storing conditions of tea, and that the differences of oxygen content after the gas replacement have influence on the effectiveness of other storing conditions. As for the aroma of tea, even 1% of oxygen is recognized to have some influence on it.

Accordingly further study is required on this matter in the case of still lower oxygen

Table 5. Analysis of variance among storing conditions of tea

Source of variation	Degree of freedom	Mean sum of squares				
		Color	Aroma	Liquor	Taste	Ascorbic acid content
Block (B)	3	1.375	0.458	5.031	1.708	788
Temp. (T)	1	630.125**	378.125**	175.781**	153.125**	16,069**
Moisture Content (W)	1	544.500**	392.000**	810.031**	242.000**	18,590**
Oxygen Content in Packed Atmosphere (O)	3	1.125	40.375**	88.031**	130.208**	10,672**
Stored time (M)	1	6.125	21.125	3.781	60.500	2,334**
First Order Interaction						
T × W	1	40.500**	32.000*	—	—	1,724*
T × O	3	—	—	20.948**	—	2,860**
W × O	3	—	—	—	—	1,095*
Second order Interaction						
T × W × O	2	—	—	—	—	1,122*
Error	8	2.156	5.297	1.969	6.141	179

** Significance at 1% level
* 〃 〃 5% 〃



Liquor Ascorbic acid content

Notice; $O_{1,2,3,4}$ $T_{1,2}$; $W_{1,2}$……Described in Table 2

Fig. 1. Interaction of oxygen content and other storing conditions.

content. In order to keep the aroma of tea to perfection it is necessary to make 100% removal of oxygen, or to perfectly carry out the storing conditions in low temperature and low moisture.

From the results of another experiment on the changes of aromatic ingredients of black tea,[6] it is also shown that the nitrogen gas packaging makes it possible to prevent the ingredients of tea from oxidation completely. These results are given in Table 6.

Head space within the package

When the quality of tea is changed owing to the oxygen contained in the head space gas in a package, its influence varies according to the amounts of the head space. In case of liquid foods, the head space can be made as small as possible in filling up the package, but for solid foods, there is some space left between grains even if the package is completely filled up and the amount of space is different according to the shape and bulk of respective granule, or it is generally dominated by the

Table 6. Relation between storing conditions and flavor of black tea (Peak area of gaschomatogram)

	Storing conditions							
Temperature	5°C				25°C			
Atmosphere	nitrogen		air		nitrogen		air	
Moisture content	4%	8	4	8	4	8	4	8
Acet-aldehyde								
Unknown		–	–	–			––	––
Propion aldehyde			+	+			+	+
Aceton or Iso-butyl-aldehyde								
Unknown								+
n-Valerialdehyde or n-Propanol							++	
n-Capronaldehyde			++	+++			+++	+++
Unknown							+	+
trans-2-hexenal							––	––

+···S×1.5 $\quad$ –···$\times\frac{1}{1.5}$

++···S×1.5~2.0 $\quad$ ––···$\times\frac{1}{1.5}\sim\frac{1}{2.0}$

+++···S×2.0

S···Standard sample stored at −20°C in nitrogen atmosphere with 4% moisture content.

bulk density.

The bulk density of tea is 0.37~0.40 g/cc in higher quality and about 0.29~0.32 g/cc in inferior quality. It is very small compared with the bulk density 0.60 g/cc of powder milk, and accordingly the head space amount is that much larger.

Since the specific gravity of tea is unknown, it is difficult to estimate a precise amount of the head space, but it is believed to be more than 50% at least.

In inert gas packaging, the effectiveness is, however, influenced by the amount of the residual oxygen in the package, and so the influence of residual oxygen must be considered from the quantitative ratio of gas and the packed foods, not from the percentage of oxygen in gas components only. These are the problems still left to be solved.