An approach to grain storage with overlapping wave

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Abstract
At present, chemical method for grain storage is still adopted as a major way of comprehensive control at home and abroad. But using a great quantity of chemicals for grain storage over a long period of time will inevitably bring about some side effects such as damaging the health of storekeepers, reducing quality of grain, strengthening drug-fast of pests and seriously polluting environment. Based on domestic situation of grain storage, foreign scientific and technological literature, electronic engineering and from the angle of environmental protection, the author puts forward a new method for grain storage using overlapping wave, makes a preliminary discussion and an approach to the principle, method, equipment, materials, treatment time, results, possibility, effectiveness and other matters of using overlapping wave for grain storage and gives appropriate opinions on them.

Introduction
Environmental protection is a worldwide focus and the development is a permanent theme of the human society. Along with the fast increase of world population and the non-stopping industrial development, the atmosphere has been polluted and the ecological condition has been ruined, which has brought about a reversed result to human beings. According to scientists, human beings in the 21st century will meet a challenge from the ever worsened environment, especially the barbaric discharge of poisonous or harmful chemical wastes and radioactive wastes which lay a direct menace to the earth the human beings live on. In 1992, the United Nations held a conference on environment and development in Rio De Janeiro, Brazil and issued the RIO DECLARATION ON ENVIRONMENT AND DEVELOPMENT, clarifying the alternative and necessary actions human beings must take in the continual development and environmental protection, stressing on the importance of international efforts for world-wide environmental protection and establishment of new partnership. The seriousness of environmental problem and the urgency of environmental protection have drawn much attention from governments, organizations, scientists and ordinary people. Environmental protection has become a common sense of human beings and a trend of today's world.

On the other hand, chemicals currently used for grain storage are still an important part of comprehensive prevention, domestical or abroad. According to an incomplete statistics, more than 7000 tons of chemical insecticide were used every year in grain fumigation in China. In which, more than 3500 tons of aluminum phosphide tablets were used. One patented tablet containing 3 gram aluminum phosphide can produce about one gram phosphine and the fumigation can discharge more than 1100 tons of virulent PH₃ each year. Therefore, a great amount of use of chemical insecticide and a long-term application of fumigation will not only impair the health of warehouse keepers, but also reduce the quality of grain and pollute the surroundings. This worries the most people and the worry is reasonable. From any side of the view, frequent use of insecticide has an unexpected result. The newly emerged problem of virulence can not be fully avoided in the application. Now, many countries have forbidden the use of insecticide and taken the procedure of re-registration. In USA, the use of dibromoethane has recently been prohibited. In Netherlands, a paper reported that methyl bromide could cause cancer (still in discussion). All these will make us more clear-headed and practical in the judgement of chemical protective methods.

Besides, drug-fastness of insect pests has been generally strengthened in every part of the world and numbers of all kinds of insect pests with such drug-fastness have now exceeded more than one hundred. For the insect pests existing in grain storage, at least 13 kinds of them were found in 1970 to have drug-fastness. In 1978, 13 kinds of coleopterans and 6 kinds of lepidopteran moths found in grain storage were known to have such drug-fastness to 77 kinds of insecticide including 12 kinds of fumigants. Up to now, the drug-fastness achieved by some kinds of insect pests have become much stronger. For example, rice weevil was studied and proved in our country to have a maximum drug-fastness of 116 times to PH₃. The general trend is that the drug-fastness of insect pests is being enhanced and numbers of nullifying insecticide are being increased. Even though there are different theories about the formation of drug-fastness of insect pests, the common knowledge is that the formation of drug-fastness is the aftermath of the

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application of chemical insecticide. The drug-fastness may be inherited and spread and therefore constitutes a menace to chemical protective methods for grain storage.

For the above-mentioned facts, scientists and technicians for grain storage are researching, with a sense of environmental protection, new methods of prevention and wipeout of insect pests in grain storage, which can replace chemical insecticide in most applications.

Enlightened by foreign literature of science and technology and considered with the current status of grain storage in our country, I recommend the adoption of technology of overlapping-wave treatment in grain storage, which is undoubtedly a new subject for study or discussion.

**Equipment and Its Working Principle**

**Equipment and auxiliaries**

(a) Overlapping-wave generator: It is a high-voltage electric wave generating device which can produce alternative current overlapping waves and its working voltage is between 10000V - 100000V (a low cycle of 50Hz - 60Hz).

(b) Conductive board: The board is made of copper, iron, aluminium and stainless steel or other metals with better conductivity.

(c) Insulator: It can insulate the electrical conductive board from the ground, such as glass insulator, porcelain insulator and Bakelite.

(d) Material to be treated by overlapping waves: grains, oil crops, edible oil and foodstuffs.

Principle and process: An overlapping-wave generator can produce AC overlapping waves and spread them over the material to be treated. The working voltage of the device is between 10000V - 100000V (a low cycle of 50Hz - 60Hz). The materials are to be treated by a high-voltage electric wave under an insulated condition from the ground. The material are thus being placed in a high-voltage and high-potential field, the molecules of the material will be effected frequently which causes an increase of electric potential of atomic nucleus and electron, forming a minimum unit and renews original energy consumed in physical movement, thus keeping the stability of material formation. Furthermore, since the material are frequently radiated by high-voltage waves, function of sterilization, wipeout of insect pests and restriction of growth of mildew can be achieved and the goal of material protection can be reached.

As shown in Figure 1, firstly install insulators to insulate conductive board from the ground, place the material on the board, connect the cable between the board and overlapping-wave generator and then switch on the power to start the treatment of material with high-voltage waves continuously or periodically.

![Diagram of overlapping-wave equipment](image)

**Fig. 1. Diagram of overlapping-wave equipment**

**Time and result of treatment**

(1) *Time of treatment*

The time of treatment varies according to the purpose, physical and chemical features, general use of the material to be treated. Some can be treated within one day or several hours and some will be treated periodically and stored for one or more than one years. Therefore, the time of overlapping-wave treatment can be set in continuous mode and periodical mode.

A report from Japan listed the times of treatment for different material, as shown in Figure 2, where the top part of the curves rising from the axial line of time are the curves appeared after the treatment with high-voltage waves.

In Figure 2, curve (a) shows the treatment of water, curve (b) shows the treatment of moisture-bearing materials, curve (c) shows the treatment of less moisture-bearing rice, flour and other foodstuffs, while curve (d)
shows the incapable treatment due to a poor insulation between the board and ground, or an unlimited time for treatment and or the improperly-fixed time of treatment in practice.

Fig. 2. Time for overlapping-wave treatment

We can see that materials with different moisture content will require different times to achieve a perfect result of treatment. That is, more moisture it has, less time it requires. Or, less moisture content, more time of treatment.

(2) Results of overlapping-wave treatment

Overlapping-wave treatment firstly showed its advantageous feature in the field of food storage technology. Overlapping-wave treatment ensures a better food storage, higher product value, less damage, lower cost, safe and no side-effect and, since it is a physical sterilization, it does not affect the hygienic quality of the food. Now it has been widely adopted in the developed countries for cake making, bakery, bean curd production, dairy products and fried foods. Reliability and the effect of overlapping-wave treatment in food storage have been proved in practice. Germ-free foodstuff factories with overlapping-wave treatment, in stead of food additives, have been developed in Japan.

Effect of overlapping-wave treatment of foodstuffs

In the research of foodstuff storage with overlapping-wave treatment in Japan, they usually treat all materials for foodstuff production, including flour, rice flour, milk, edible oil, eggs and water. The treated materials have fewer bacteria and their physical character has been improved, their contents of starch, protein and fat have been stabilized, their integration with water has been enhanced and their characteristics for processing have been optimized. Furthermore, the solubility and permeability of water have been strengthened to have better blending with foodstuffs, since the water has more stable molecules after overlapping-wave treatment. Meanwhile, the moisture retention of the treated foodstuff can be improved and it will be kept from mildewing.

In food industry, quality and storage are the top concerns above all. Since foods are liable to go bad, chemical additives (preservatives) are often used, in order to prolong the shelf-life. Now the overlapping-wave treatment has resolved this problem. The appearance, smell and taste of the treated food have all been improved.

According to a test in Japan, the foodstuff after a one-shot overlapping-wave treatment, providing that no any additive to be used, had a better mildew-proof effect and lower rate of deterioration. Steamed bread could be shelved for 4 - 5 days in summer without any change. Packed cakes could be stored for one or one and a half months. Bean curd which is mostly liable to turn sour could be kept for a longer time, since the water separation became less and numbers of bacteria were reduced after the overlapping-wave treatment. As the length of this article is limited, more examples will not be mentioned here, see Table 1 - Table 5.
Table 1. Storage of foodstuffs and change of numbers of bacteria

<table>
<thead>
<tr>
<th>Factors</th>
<th>One day</th>
<th>Two days</th>
<th>Three Days</th>
<th>Four Days</th>
<th>Five Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A Contrast Group</td>
<td>$4.5 \times 10^3$</td>
<td>$9.0 \times 10^4$</td>
<td>$6.5 \times 10^6$ (pie)</td>
<td>$9.2 \times 10^6$</td>
<td>$1.5 \times 10^7$</td>
</tr>
<tr>
<td>Testing Group</td>
<td>$1.2 \times 10^2$</td>
<td>$9.4 \times 10^3$</td>
<td>$9.4 \times 10^4$</td>
<td>$8.2 \times 10^5$</td>
<td>$7.2 \times 10^6$ (pie)</td>
</tr>
<tr>
<td>B Contrast Group</td>
<td>$4.4 \times 10^3$</td>
<td>$7.0 \times 10^4$</td>
<td>$6.5 \times 10^5$</td>
<td>$4.5 \times 10^6$ (pie)</td>
<td>$1.6 \times 10^7$ (pie)</td>
</tr>
<tr>
<td>Testing Group</td>
<td>$6.5 \times 10^2$</td>
<td>$1.0 \times 10^4$</td>
<td>$5.2 \times 10^5$</td>
<td>$8.3 \times 10^5$</td>
<td>$6.7 \times 10^6$</td>
</tr>
<tr>
<td>C Contrast Group</td>
<td>$4.0 \times 10^4$</td>
<td>$5.0 \times 10^5$</td>
<td>$7.2 \times 10^5$ (pie)</td>
<td>$2.3 \times 10^7$</td>
<td>$3.0 \times 10^6$ (pie)</td>
</tr>
<tr>
<td>Testing Group</td>
<td>$7.8 \times 10^2$</td>
<td>$2.5 \times 10^3$</td>
<td>$4.5 \times 10^4$</td>
<td>$1.0 \times 10^5$</td>
<td></td>
</tr>
</tbody>
</table>

Cut the cake or bread into slices of 15–20 mm thickness and store them in a thermostat under temperature of 30–32°C.

Table 2. Weight loss of bread by moisture activation and storage

<table>
<thead>
<tr>
<th></th>
<th>Two days</th>
<th>Three days</th>
<th>Four days</th>
<th>Six days</th>
<th>Loss rate</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contrast group</td>
<td>17.0 g.</td>
<td>11.5 (5.5)</td>
<td>10.7 (6.3)</td>
<td>10.4 (6.5)</td>
<td>10.3 (6.7)</td>
<td>39.4 %</td>
</tr>
<tr>
<td>Testing group</td>
<td>21.2 g.</td>
<td>14.3 (6.9)</td>
<td>13.4 (7.8)</td>
<td>13.1 (8.1)</td>
<td>12.9 (8.3)</td>
<td>39.2 %</td>
</tr>
<tr>
<td>Contrast group</td>
<td>24.5 g.</td>
<td>19.2 (5.3)</td>
<td>17.2 (7.3)</td>
<td>16.7 (7.8)</td>
<td>16.5 (8.0)</td>
<td>32.6 %</td>
</tr>
<tr>
<td>Testing group</td>
<td>22.0 g.</td>
<td>17.6 (4.4)</td>
<td>15.6 (6.4)</td>
<td>15.1 (6.9)</td>
<td>14.5 (7.5)</td>
<td>34.1 %</td>
</tr>
</tbody>
</table>

Cut the bread into slices of 10–12 mm thickness and put one into a PE bag, seal it and then put it near a drafty window.

Table 3. Moisture and moisture activation of foodstuffs

<table>
<thead>
<tr>
<th></th>
<th>Moisture (3 days)</th>
<th>Activation (3 days)</th>
<th>Moisture (5 days)</th>
<th>Activation (5 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contrast group</td>
<td>43.8 %</td>
<td>0.984</td>
<td>43.2 %</td>
<td>0.982</td>
</tr>
<tr>
<td>Testing group</td>
<td>45.0 %</td>
<td>0.975</td>
<td>44.8 %</td>
<td>0.970</td>
</tr>
</tbody>
</table>

1 5 kg in each 0.03 mm PE bag

Table 4. Scalded wheaten food by overlapping-wave treatment and numbers of bacteria.

<table>
<thead>
<tr>
<th>Items to be treated</th>
<th>General numbers of bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foodstuffs and scaling water</td>
<td>$1.1 \times 10^4$</td>
</tr>
<tr>
<td>Foodstuffs and products</td>
<td>$2.8 \times 10^4$</td>
</tr>
<tr>
<td>Foodstuffs, scaling water and products</td>
<td>$1.0 \times 10^4$</td>
</tr>
<tr>
<td>Products</td>
<td>$6.8 \times 10^4$</td>
</tr>
<tr>
<td>Items not treated by overlapping waves</td>
<td>$4.8 \times 10^5$</td>
</tr>
</tbody>
</table>

Table 5. Change of numbers of bacteria in bean curd making (stored under 20°C)

<table>
<thead>
<tr>
<th></th>
<th>3 hours</th>
<th>48 hours</th>
<th>72 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contrast group</td>
<td>60,000</td>
<td>72,000,000</td>
<td>180,000,000</td>
</tr>
<tr>
<td>Testing group</td>
<td>5,500</td>
<td>10,000,000</td>
<td>55,000,000</td>
</tr>
</tbody>
</table>

Table 6. Result of overlapping-wave treatment in oil processing

Edible oil can offer a human body with quality of heat, necessary fatty acid, oil-soluble vitamins and endows foods with peculiar taste, which is a kind of indispensable foodstuff needed for daily life. In the storage of oil products, souring is the typical headache. Souring is usually caused by oxidation which produces aldehyde or keto compounds. Oxidation and deterioration may occur if the oil products undergo a high temperature of 200°C, or are not properly stored or stored for a very long time. Sour oil products contain no nutritive content but toxicity instead. Recent researches show that a long-term use of deteriorated oil products may cause cancers.

Common treatment for sour oil is the alkali process ($RCOOH + NaOH → RCOONa + H_2O$). The alkali process can increase the quality of oil products and improve the stability of storage, but the shortcomings are large oil consumption, high cost and complicated treatment.

Now the Japanese researchers asserted that the problem of oil oxidation can be well resolved by overlapping-wave treatment.

Overlapping waves form on the curves of high voltage AC sine wave, produce at random higher harmonic waves and make these waves overlapped. Higher harmonic waves are more projecting waves than the curves of sine wave, which are formed instantly under a high-voltage load. The overlapping-wave generator sends out electric waves and the oil molecules are affected by atomic dimension, which
strengthens the integration of oil molecules and prevents from oil oxide decomposition and aggregation.

Advantages of the use of overlapping-wave generator are to restore the oxidized sour oil, to decrease viscosity of the oil, to minimize the consumption of oil (save 20 - 50%) and to gain a lower acidic value. Peroxide value was tested under high temperature and the results in ten days later were 160 for contrast group and 60 for testing group. It has a little power consumption because it outputs no current.

The followings are the results of frying oil treated by overlapping waves for fried foodstuff industry in Japan:
(A) Effective restriction of oxidation of the frying oil. (see Figure 3.)
(B) Restriction of oil oxidation in foodstuffs. (see Figure 4.)
(C) Enhancement of the movement of thermal molecules of oil, which increases the temperature of foodstuffs and prolongs the storage.

![Graph showing comparison of OAV](image)

**Fig. 3.** Comparison of AOV

Procedure of test in Figure 3: Prepare one kilogram of fish and fry it in 2 liter frying oil at a temperature of 140°C - 150°C. Treat the fried fish with overlapping waves for 12 - 15 hours every day.

Procedure of test in Figure 4: The frying oil was treated by overlapping waves for 15 hours and stored in thermostat at a temperature of 60°C and the oil sample was tested periodically.

Measures in Figure 5 should be followed when automatic treatment of overlapping waves is used for oil products: Firstly install the tank on an insulator and turn on the solenoid valve to fill the oil in. When the tank is filled to the full level, which is adjustable, turn off the valve and then switch on the overlapping-wave generator. After a time treatment, pump the oil to a secondary tank for discharging.

### Possibility of the Utilization of Overlapping-waves in Grain Storage

The principle and process of overlapping-wave generator have been explained and advantages of the application have been convinced. The treated foodstuffs have an improved physical character and stability of starch, protein and fat. The treatment brings about the effects of sterilization, mildewing restriction and prolonged time for storage. Besides, the treated oil can be kept from oxide decomposition and aggregation. Even the sour oxidized oil can be restored. Then, can we use overlapping waves in grain storage and oil crops? The answer is yes.

(1) Grains and oil crops have vital force and the existing condition and distributing property of the moisture inside the grain are originally endowed. Every kind of seeds has its own appropriate moisture content and a certain moisture content can offer certain conductivity. According to electrical engineering, the insect pests are also conductive mediums, which will be shocked and wiped out by high-voltage electrical waves. The high-voltage electrical waves have also sterilizing and bacteria-inhibiting effects for grain microorganisms. This is the theoretical basis for the utilization of overlapping-
(2) Chemical contents of grains are protein, starch, sugar, fiber, fat, ash and moisture. The past scientific research proved that the chemical content of grains has a close relationship with its storability. The application of overlapping-wave treatment can help improve physical characters of grains and make the chemical contents more stable, thus postponing the staleness and enhancing the storability of grains.

Fig. 4. Comparison of POV
POV is the value increased by oil oxidation

Fig. 5. Diagram of overlapping-wave treatment of oil

(3) The hold of vital force is the important indication of freshness of grains. The loss of vital force of grains may be caused by external factors or intrinsic factors. The external factors are long-time exposure to heavy sunshine, microorganism and insect pests. The intrinsic factors are the accumulation of toxic substance, fat oxidation and consumption of metabolic composition. Staleness of grains is generally caused by the increase of
acidity, especially by the change of amount of fatty acid, which is the result of staleness caused by microorganism. Researches also proved that the increase of fatty acid of wheat is accompanied with the reduction of germination percentage and mildew of wheat.

Movement of microorganism often expedites respiration of seeds and accumulation of toxic substance, speeds up the time of deterioration, thus weakening the vitality of seeds. Since microorganism has a function of respiration, it raises the temperature of grain heap and quickens the metabolism of grains. And, since microorganism propagates and excretes toxic substance, it brings about deterioration to the active protein.

Insect pests nibble grains on the one hand, break the shape of every grain and cause ruinous loss. On the other hand, since insect pests have strong life movement, the heat and moisture it produces will be accumulated in the grain heap, which strengthens the respiratory function of grains, worsens the storing condition and effects directly or indirectly the life of grains.

Overlapping-wave treatment is a kind of physical sterilization or insecticide. The treatment can not only reinforce the energy of grains consumed in physical movement to stabilize the material formation, but also restrain the activity of microorganism, wipe out or prevent from insect pests, in order to delay the change of grain quality and extend the life of grains.

**Question and Discussion**

(1) The utilization of overlapping-wave treatment in grain storage shows much advantages. Since it is a physical treatment, it gives no pollution to grains and the surroundings. The designing capacity is at user's option. The device can be stationary or movable and it is easy to install, adjust and operate. It has a lower power consumption and lower cost of treatment. It is worthy to be widely adopted. Furthermore, it can be easily automated for oil treatment. There have been reports about the successful application of overlapping-wave treatment for food storage in other countries, but any information of the application for grain storage has been obtained yet. The above explanation is merely a theoretic study based on the working process and effects of overlapping-wave treatment. I hope others to join in this new research and make it more perfect.

(2) Moisture content of grains has some relations with conductivity. When there is lower moisture content, there is a less conductivity. When there is higher moisture content, there is greater conductivity. The relationship is referred to Figure 6.

![Fig. 6. Relationship between conductivity and moisture content of grains](image-url)
Besides, the conductivity is not only related with moisture content of grains, but also with the variety, origin, environmental temperature, pressure of grain heap and content of impurities. All of these should be considered in the designing of overlapping-wave generators. An adjustable type is more applicable.

(3) The overlapping-wave treatment is carried out under alternative current high-voltage electrical waves and safety precautions should be considered before start. Meanwhile, the moisture content of grains should not exceed the safety level of storage. Content of impurities should also not go beyond the specified standards. The treatment should be proceeded in a place free of pollution, outside disturbance and moisture-proof. Do not consider only conductivity of grains and short-term effects, to neglect the safe content of moisture and standard for content of impurities. This may make you attend to one thing and lose another, to forget the actual purpose of grain storage. If time of storage is longer than several months or above one year, an intermittent overlapping-wave treatment would be applied.

(4) The final goal of the development and application of overlapping-wave treatment in grain storage is to enhance the quality and storability of grains. According to a report from Japan, better results would be achieved if a comprehensive utilization of overlapping waves, microwaves, γ-radiation and ultraviolet radiation is adopted.

References


