The use of food waste as a protein source for animal feed - current status and technological development in Japan

Tomoyuki Kawashima
National Institute of Livestock and Grassland Science
Japan

INTRODUCTION
Food waste used to be well utilized as animal feed in Japan. The use of food waste, however, declined due to the introduction of commercial concentrate feed and high performance exotic breeds, accompanied by a change of producer’s strategy in pursuing more efficient production. The quantity and quality of food waste also altered due to a change in lifestyle. The system used in the past can no longer be applied. The relatively low price of imported animal products and feed, due to foreign currency rates, has also been disturbing the efficient use of food waste as animal feed in Japan.

While some of the food industry’s by-products, whose quality and quantity do not fluctuate, are being used as a part of dried concentrate feed or Total Mixed Rations (TMR), the quality of most food wastes fluctuates considerably and its safety is of concern. Consequently, its use as animal feed is limited. Such wastes have been incinerated and put into landfill. This process induces emission of global warming gases and toxic substances such as dioxin and heavy metals. It is reported that the amount of food waste in Japan is 20 million tonnes per year, of which the amount used for fertilizer and feed are 3 percent and 5 percent, respectively (Table 1).

In order to alleviate the environmental burden from food waste, a food-recycling law has been in force since May, 2001. Under this legislative system, many projects have been initiated. Most of activities have been related to the production of compost but, as there has been limited acceptance of this by crop farmers, it was proposed that the waste which can be safely used should be processed into feed.
TABLE 1
Disposal of food waste in Japan

<table>
<thead>
<tr>
<th>Type</th>
<th>Generation (t/annum)</th>
<th>Disposal Incineration/landfill</th>
<th>Recycled Compost</th>
<th>Feed</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal Waste</td>
<td>16 000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Commercial waste</td>
<td>6 000</td>
<td>15 950</td>
<td>50</td>
<td>-</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td>Household waste</td>
<td>10 000</td>
<td>50 (99.7%)</td>
<td>0.3%</td>
<td></td>
<td></td>
<td>(0.3%)</td>
</tr>
<tr>
<td>Industrial Waste</td>
<td>3 400</td>
<td>1 770 (52%)</td>
<td>470 (14%)</td>
<td>1 040</td>
<td>120</td>
<td>1 630</td>
</tr>
<tr>
<td>Total commercial waste</td>
<td>9 400</td>
<td>7 750 (83%)</td>
<td>490 (5%)</td>
<td>1 040</td>
<td>120</td>
<td>1 650</td>
</tr>
<tr>
<td>Household waste</td>
<td></td>
<td></td>
<td></td>
<td>120</td>
<td></td>
<td>(1%)</td>
</tr>
<tr>
<td>Total</td>
<td>19 400</td>
<td>17 720 (91%)</td>
<td>520 (3%)</td>
<td>1 040</td>
<td>120</td>
<td>1 680</td>
</tr>
</tbody>
</table>

Source: Derived from the statistics of Ministry of Health and Welfare (1996)

In September 2001, just after the introduction of this law, an incidence of Bovine Spongiform Encephalopathy (BSE) was reported in Japan. So far, only three cases of BSE have been diagnosed. This created a serious problem for the activities promoted by the food-recycling law. The use of food waste containing mammalian meat was temporarily banned. It was announced later by the Minister of Agriculture, Forestry and Fisheries, however, that food waste containing meats, which were originally processed for human consumption, could be fed to swine, but not to ruminants.

To change the feeding system from the one based on imported concentrate to a recycling system, it is necessary to develop a series of technologies, as follows:

Feed evaluation
- Processing
- Feeding system
- Meat quality
- Feed safety.
In this report, the current status of the use of food waste as animal feed and the development of related technologies will be discussed mainly for swine production.

**PROCESSING OF FOOD WASTE FOR ANIMAL FEED**

The methods of processing food waste for animal feed can largely be classified into the following three categories:

- dehydration,
- silage, and
- liquid feeding

Distribution range, delivery system, costs of processing, ease of preservation, etc., differ depending upon the processing method, which is mainly related to the differences in moisture contents.

After the enforcement of the food recycling law, several kinds of model plants were built up to manufacture feed from food waste using dehydration. The methods involved in dehydration are:

- conventional dehydration by heat,
- fermentation-dehydration, and
- fry cooking.

The dry matter of products processed by these methods ranged from 70 to 97 percent. Farmers can feed it to swine without any modification of their feeding system if feed composition is appropriate, or the products can be used as ingredients for commercial concentrate feeds.

In Sapporo city, the Sapporo Kitchen Garbage Recycle Centre was set up. This collects 50 tonnes of garbage from a total of 188 schools, hospitals and companies and processes it into dehydrated feed by fry-cooking. Fry cooking is a new system of dehydrating food waste according to the method of Templar 21\(^1\) in which it is cooked in waste vegetable oil under reduced pressure at relatively low temperature (about 110°C). Variation of chemical composition of this feed is shown in Table 2 (Sayeki et al., 2001).

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\(^1\) see the details: [http://www.mes.co.jp/english/product/environ/a04.html](http://www.mes.co.jp/english/product/environ/a04.html)
TABLE 2
Chemical composition of dehydrated meal manufactured from garbage by fry cooking (n=59) (%)

<table>
<thead>
<tr>
<th>Item</th>
<th>Organic matter</th>
<th>Crude protein</th>
<th>Crude fat</th>
<th>Carbohydrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>92.2</td>
<td>23.4</td>
<td>9.7</td>
<td>59.1</td>
</tr>
<tr>
<td>Maximum</td>
<td>94.7</td>
<td>25.8</td>
<td>12.4</td>
<td>67.7</td>
</tr>
<tr>
<td>Minimum</td>
<td>90.2</td>
<td>19.8</td>
<td>7.2</td>
<td>52.0</td>
</tr>
<tr>
<td>SD</td>
<td>0.9</td>
<td>1.2</td>
<td>1.4</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Source: Sayeki et al., (2001)

Dry matter content is about 95 percent with little fluctuation. It is generally understood that the quality of garbage fluctuates considerably. However, the variation of chemical composition in this manufactured feed ranged from only 1.2 to 1.8 percent. It is suggested, therefore, that the chemical composition of garbage becomes constant when it is collected from many places. The manufactured feed is approved by the Ministry of Agriculture, Forestry and Fisheries and the certified nutritive values are listed in Standard Tables (National Agricultural Research Organization, 2001) (Table 3). Consequently, it can be used as an ingredient of commercial concentrate feed.

TABLE 3
Composition, digestibility and nutritive value of dried waste food for swine and poultry

<table>
<thead>
<tr>
<th>Moisture</th>
<th>CP</th>
<th>EE</th>
<th>NF</th>
<th>CF</th>
<th>CA</th>
<th>Digestibility (%)</th>
<th>TDN</th>
<th>DE</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>C</td>
<td>E</td>
<td>NF</td>
</tr>
<tr>
<td>DM</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>E</td>
<td>4.5</td>
<td>7.8</td>
<td>60</td>
</tr>
<tr>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>E</td>
<td>54.1</td>
<td>7.8</td>
<td>60</td>
</tr>
</tbody>
</table>

Source: National Agricultural Research Organization. 2001

Ensiling is another method of processing food waste for feed. However, it is not practically utilized in swine production due to: 1) cost of preparation and transportation of silage, and 2) silage cannot be delivered through conventional feeding systems for concentrate feed.

Liquid feeding is not popular in Japan in comparison with the situation in
Europe. There are only a few farmers using liquid feed from food waste. It requires a high investment to renew the feeding system. However, it has great potential to exploit high moisture food waste as an animal feed. As dehydration of the food waste is unnecessary, the cost of processing is considerably lower and little protein is lost during the low temperature process.

Fermented liquid feeding is a process that involves fermentation to decrease pH and extend shelf life. During the process of fermentation, anti-nutritional factors, such as phytate and non starch polysaccharide, can be broken down by either endogenous or exogenous enzymes. However, lactic fermentation creates a probiotic effect on animals (Brooks, 2001) and a Government supported research project has just been initiated to develop fermented liquid feed.

Swill is the traditional method of utilizing garbage for swine feeding. In 1998 in Japan, 1004 farmers used swill to feed 194,186 animals, while the total number of swine farmers and total number of swine were 14,400 and 9.8 million head respectively. It is often reported that the fat of pigs given large amounts of swill becomes soft, and the price of pork is reduced. In order to solve this problem, farmers in Osaka established a group which gets together periodically to compare their pork and to discuss methods of improving meat quality when the pigs are given large amounts of food waste. To overcome this problem, the farmers have developed a common approach to utilizing different kinds of food waste and aim to collect low fat materials and as a result prolong the fattening period. As plate wastes from hospitals are low in fat and salts, they provide a good source of feed. By feeding these, the quality of pork is dramatically improved and some shows high marbling, which increases its value. These farmers therefore make a lot of profit due to the improved price and low cost of feed.

**The effect of processing on the availability of protein**

Wastes are heated for dehydration and sterilization. Temperatures for this process range from 70 to 230°C but higher temperatures tend to decrease the availability of protein. Sayeki et al. (personal communication) examined reports describing the digestibility of nutrients in dehydrated food waste produced by different methods. From these they established relationships between the nutrient content and its digestible fraction. While regression coefficients in Ether Extract (EE), Nitrogen Free Extractives (NFE) and carbohydrate (total of Crude Fibre, (CF) and NFE) were very high, that of Crude Protein (CP) was low. The low uniformity of CP is considered to be due
to the process of dehydration. Each method applied a different temperature in the range 60 to 130 °C. During the process of dehydration, protein was degenerated and the degree of degeneration was proportional to the temperature. The difference in heating temperature would therefore seem to be the major reason for the low uniformity in protein.

The degeneration of protein during the process of heat treatment is one of the most serious problems in the utilization of food waste as animal feed. It is important, therefore, to develop an analysing method to monitor the magnitude of degeneration. Various feed samples, which were produced from food waste, such as tofu cake, bread, rye bran, vegetables etc., were analysed by an in vitro enzymatic method using pepsin and pancreatin (Boisen and Fernandez, 1995), and a detergent analysis described in Cornell Net Carbohydrates and Protein System (CNCPS, Sniffen et al., 1992). Nitrogen depletion rates of the food waste analysed by the in vitro enzymatic method were affected by the temperature of the dehydration treatment and its duration. These depletion rates negatively correlated with detergent insoluble protein fractions. It suggested that detergent insoluble protein fractions could be utilized to estimate availability of protein in feed for swine (Sayeki et al., personal communication).

An analysis method for these protein fractions is also being developed with Near infrared spectroscopy (NIRS). Further advances in the technology for predicting protein availability in processed food waste by the in vitro method or NIRS would promote greater use of food waste for animal feed.

**Detection of animal materials in processed feed**

The occurrence of BSE in Japan has lead to serious concern about feed safety. Methodologies for the detection and identification of animal materials in feed have been reported since BSE was recognized in the United Kingdom in 1986. Therefore, detection of animal materials in feed processed from food waste is also important. There are several methods of detection, such as microscopic observation, NIRS, Enzyme-linked Immunoasorbent Assay (ELISA) and Polymerase Chain Reaction (PCR) (Momcilovic and Rasooly, 2000). The National Institute of Livestock and Grassland Science has developed a PCR method for the detection of materials from ruminants, pigs and chickens with primers designed using a sequence of Art2, PRE-1 and CR1 short interspersed repetitive elements (SINEs), respectively. These primers are able to amplify each SINE with the total DNA extracted from feed. Each primer’s sensitivity
for detecting animal materials is less than 0.01 percent. The method can therefore be used to detect the micro-contamination of feed with animal materials (Tajima et al., personal communication).

CONCLUSION
Self-sufficiency of food in Japan is only 40 percent. The very low self-sufficiency of animal feed (only 20 percent) is one of the major reasons for this and the poorly balanced feed supply makes the livestock sector unsustainable. The use of recycled food waste for feed is an effective method of improving feed self-sufficiency and reducing the environmental burden from food waste.

In many Asian countries, urbanization induces an imbalance of nutrient accumulation. While large amounts of nutrient accumulate in urban areas as food waste, livestock in the countryside are suffering from malnutrition. Technological development in the use of food waste for animal feed will contribute to the improvement of self-sufficiency of food. This will help correct the imbalance in nutrient accumulation and make animal-agriculture more sustainable.

REFERENCES


