

# USE OF AGRO-INDUSTRIAL BY-PRODUCTS AS ANIMAL FEEDS IN KOREA

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## ABSTRACT

*The yield of by-products from food processing which are suitable as livestock feed is determined by two main factors, the dietary habits of human beings and the production capacity of alternative feed resources. The second of these is often determined by the land area available for feed production. Korea is a small country with a high population density, and lacks natural feed resources. It is dietary habits therefore which mostly determine which by-products are available as livestock feed.*

*The main food processing by-products available in Korea are brewers' grain and distillers' grain from the alcohol industry, condensed molasses fermentation solubles, fermented soybean paste residues from the making of sauces and seasonings, by-products from the manufacture of instant noodles, soybean curd residues, and ginseng meal from medicinal herbs. Jeju island in the south of Korea produces a relatively large amount of citrus, and generates considerable amounts of citrus pulp when these are processed into juice.*

*Korea imports a large quantity of feed resources (15 million mt per year), mainly from USA and Southeast Asia. Utilization of indigenous by-products for livestock feed is urgently required, to raise the international competitiveness of Korea's livestock production. Unfortunately, most by-products are at present being discarded as wastes, which causes environmental pollution. Therefore, changes in government policy might be necessary to facilitate the utilization of by-products, while more research on their use is also needed.*

## INTRODUCTION

The need for high efficiency in livestock production, and the change from smallholder agriculture to larger mechanized farms, has forced Korean farmers to use mainly conventional feeds, at the expense of most non-conventional feed resources. Although the quantity of agro-industrial by-products produced in Korea is relatively large, most of these are disposed of by dumping, burning or burying. Most processing by-products have a high moisture content, which means they often need to be dried before being used by farmers. If they are not dried, the high moisture content causes difficulties in storage, transportation and handling, which constrains

the regular use of these materials as animal feed. Proper drying greatly enhances the quality of these by-products. Table 1 shows the types of agro-industrial by-products available in Korea, while this paper reviews their utilization as feed resources.

## UTILIZATION OF AGRO-INDUSTRIAL BY-PRODUCTS IN KOREA

### By-Products from the Alcohol Industry

Brewers' grain and distillers' grain are two major by-products from alcohol production in Korea. The quantity of the two by-products are estimated to be 200 - 300 thousand mt, and 50 thousand

Keywords: Brewers' grain, by-products, citrus pulp, food processing, ginseng meal, Korea, livestock feed, molasses fermentation solubles

Table 1. List of agro-industrial by-products available in Korea

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|   |
|---|
| I. Industrial by-product  |
| Alcohol fermentation industry                                       |
| Brewers' grain and distillers' grain                                |
| Sauce and seasoning industry  |
| Molasses fermentation solubles and fermented soybean paste residues |
| Fruit and vegetable processing                                      |
| Fruit pulp, peel and juice by-products                              |
| Vegetable oil industry  |
| Soybean oil meal, rape seed meal and sesame seed meal               |
| Wood industry   |
| Sawdust   |
| Human food industry   |
| Bakery by-products and ramon (noodle) meal                          |
| II. By-products of animal origin                                    |
| Slaughterhouse and rendering industry                               |
| Meat meal, bone meal, animal fat and tallow, and feather meal       |
| Feeds from the fish industry  |
| Fish meal and fish oil  |
| III. By-products from medicinal herbs                               |
| Ginseng meal  |

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mt, respectively.

#### ***Brewers Grain***

Brewers' grain is a by-product from brewing barley to make beer, and contains non-soluble materials such as barley husk. The nutrient composition of brewers' grain produced in Korea is shown in Table 2 Table 3. The crude protein content is similar to, or a little higher than, that of corn germ meal but the TDN (Total Digestible Nutrients) level is lower. The by-pass protein content is estimated as 57%. Brewers' grain is bulky, and is often used as a supplement for lactating cows. Research results shown in Table 4 indicate that adding 10% dry brewers' grain to the diet of fattening pigs reduces their daily weight gain, but improves their carcass quality. The price of brewers' grain was US\$0.04/kg, compared to US\$0.21/kg for commercial mixed rations for growing pigs. The lower price of brewers' grain, together with the improved carcass quality, resulted in 16% higher profits in this study.

#### ***Distillers' Grain***

Raw materials used for distillation include rice, tapioca and sweet potato. The nutritional characteristics depend on the raw materials, as shown

in Tables 2 and 3. Distillers' grain has a relatively high crude protein content, but a low energy content. The palatability is rather poor, so less than 5% should be included in the rations of most animals. As well as the low energy level, low lysine and tryptophan values may limit the level of distillers' grain included in the diet of growing-finishing swine. The addition of oil seed meal may help correct a deficiency of these nutrients.

Essentially, there are no facilities in Korea to process the by-products of alcohol fermentation. This limits the use of these potential feed resources. Farms near breweries and distillation factories occasionally obtain these by-products in a wet form and use them as feed.

#### **By-Products from the Making of Sauces and Seasonings**

##### ***Condensed Molasses Fermentation Solubles (CMS)***

CMS is the organic residue of microbial fermentation, produced in making monosodium glutamate (MSG) from raw sugar and molasses.

The chemical composition and physical properties of CMS are shown in Table 5. With a moisture content of 42.0%, the crude protein con-

Table 2. Chemical composition and TDN of brewers' grain and distillers' grain in Korea

| Feed type         | Dry matter (%)      | Crude protein (%) | Extractable energy (%) | Crude fiber (%) | Calcium (%) | Nitrogen free extract (NFE) | Total digestible nutrients |       |
|-------------------|---------------------|-------------------|------------------------|-----------------|-------------|-----------------------------|----------------------------|-------|
|                   |                     |                   |                        |                 |             |                             | Cattle                     | Swine |
| Brewers' grain    | 27.90 <sup>a</sup>  | 8.01              | 1.90                   | 6.40            | 1.80        | 9.70                        | 19.84                      | 11.71 |
|                   | 100.00 <sup>b</sup> | 29.03             | 6.81                   | 22.94           | 6.45        | 34.77                       | 71.11                      | 41.97 |
| Distillers' grain | 38.81 <sup>a</sup>  | 12.69             | 1.06                   | 4.31            | 0.47        | 20.28                       | -                          | -     |
|                   | 100.00 <sup>b</sup> | 32.70             | 2.73                   | 11.11           | 1.21        | 52.25                       | -                          | -     |
| Rice              | 11.19 <sup>a</sup>  | 2.29              | 0.78                   | 3.06            | 0.57        | 4.49                        | 6.80                       | -     |
|                   | 100.00 <sup>b</sup> | 20.46             | 6.97                   | 27.35           | 5.09        | 40.13                       | 60.73                      | -     |
| Sweet potato      | 90.06 <sup>a</sup>  | 10.95             | 4.17                   | 35.45           | 11.5        | 27.96                       | 40.06                      | -     |
|                   | 100.00 <sup>b</sup> | 12.16             | 4.63                   | 39.36           | 12.80       | 31.05                       | 44.48                      | -     |
| Tapioca           | 23.22 <sup>a</sup>  | 2.86              | 0.95                   | 8.64            | 4.05        | 6.72                        | 9.64                       | -     |
|                   | 100.00 <sup>b</sup> | 12.32             | 4.09                   | 37.21           | 17.44       | 28.94                       | 41.53                      | -     |

a Fresh form

b Dry form

Table 3. Amino acids in brewers' and distillers' grain

| Amino acid    | Spent grain after brewing | Spent grain etc. after distilling |        |         |              |        |
|---------------|---------------------------|-----------------------------------|--------|---------|--------------|--------|
|               |                           | Sweet potato                      |        | Tapioca | Naked barley |        |
|               |                           | Fine                              | Coarse |         | Fine         | Coarse |
| Cystine       | 0.052                     | 0.282                             | 0.196  | 0.093   | 0.425        | 0.191  |
| Methionine    | 0.476                     | 0.393                             | 0.235  | 0.121   | 0.613        | 0.234  |
| Aspartic acid | 1.729                     | 2.330                             | 1.499  | 0.611   | 2.442        | 1.093  |
| Threonine     | 1.007                     | 0.964                             | 0.550  | 0.315   | 1.272        | 0.557  |
| Serine        | 1.442                     | 1.016                             | 0.570  | 0.332   | 1.396        | 0.613  |
| Glutamic acid | 6.136                     | 2.166                             | 1.303  | 0.813   | 4.578        | 2.014  |
| Proline       | 3.095                     | 0.874                             | 0.489  | 0.689   | 1.557        | 0.889  |
| Glycine       | 0.746                     | 0.960                             | 0.874  | 0.329   | 1.395        | 0.464  |
| Alanine       | 1.304                     | 1.525                             | 0.661  | 0.379   | 1.701        | 0.796  |
| Valine        | 1.381                     | 1.379                             | 0.785  | 0.477   | 2.102        | 0.857  |
| Ileucine      | 1.041                     | 0.977                             | 0.560  | 0.353   | 1.383        | 0.574  |
| Leucine       | 2.314                     | 1.577                             | 0.913  | 0.560   | 2.558        | 1.036  |
| Tyrosine      | 0.915                     | 0.761                             | 0.319  | 0.170   | 1.079        | 0.416  |
| Phenylalanine | 1.603                     | 1.143                             | 0.664  | 0.318   | 1.494        | 0.664  |
| Lysine        | 1.025                     | 0.804                             | 0.424  | 0.339   | 1.074        | 0.487  |
| Histidine     | 0.814                     | 0.432                             | 0.275  | 0.122   | 0.588        | 0.262  |
| Arginine      | 1.405                     | 0.729                             | 0.365  | 0.206   | 1.112        | 0.530  |

Source: Composition of Korean Feedstuffs

Table 4. Effects of brewers' grain on growth performance of growing-finishing pigs

| Item                                       | Control | Treatment           |                      |
|--|---------|---------------------|----------------------|
|  |         | Brewers' grain (4%) | Brewers' grain (10%) |
| Experimental period (body wt. 30 - 105 kg) |         |                     |                      |
| Daily grain, kg                            | 0.70    | 0.68                | 0.64                 |
| Feed intake, kg                            | 2.42    | 2.71                | 2.97                 |
| Feed efficiency                            | 3.45    | 4.03                | 4.68                 |
| Carcass quality                            |         |                     |                      |
| Live weight, kg                            | 110.9   | 110.6               | 106.9                |
| Carcass weight, kg                         | 69.9    | 70.6                | 68.1                 |
| Carcass rate, %                            | 62.8    | 63.8                | 63.7                 |
| Back fat depth, cm                         | 1.69    | 1.63                | 1.30                 |
| Carcass grade                              | A       | 1                   | 3                    |
|  | B       | 4                   | 6                    |
|  | C       | 6                   | 1                    |

Source: Kim *et al.* 1992

tent is 45.0%, with negligible amounts of crude fiber (1%) and no crude fat. The viscosity of CMS is 28.0, while that of molasses is 10.0. Therefore, a CMS supplement may decrease the viscosity of molasses, making it a more efficient feed resource. In addition, since CMS has a freezing point of -40°C, it can be preserved during the winter.

Table 6 indicates the mineral composition of CMS. Chloride is the most common mineral, (3.04%) followed by potassium (0.74%) and sulfur (0.67%). In terms of trace minerals, lead, cadmium and chromium are present at levels of 0.356, 0.037 and 0.330 ppm, respectively. These are below the minimum permitted levels for livestock feed.

The level of total amino acids is 9.88%. Of these, 5.52% is glutamic acid, 1.47% alanine acid, and 1.20% aspartic acid (Table 7). It should be noted that this high concentration of glutamic acid is because CMS is a by-product of MSG fermentation products.

Since CMS contains a high level of crude protein (45.0%), it is a good potential feed resource. Particularly, high levels of non-protein nitrogen (32.0%) in CMS have attracted ruminant nutritionists to study whether it can replace the NPN in conventional feeds. As much as 70% of the CMS produced annually in Korea (around 18,000 mt) was being dumped in the sea as waste, at a cost of approximately US\$3.5 million. However, after Cha

*et al.* (1990) and Maeng *et al.* (1990) suggested the utilization of CMS for feed, many trials have been conducted. CMS is now available in Korea as a feed, under the brand name of Molatein.

A study was conducted in our laboratory to investigate the effects of CMS on the feed efficiency and growth performance of Korean native cattle (Hanwoo), and to determine the appropriate level of CMS in their diet.

Seventy-eight male cattle, weighing on average 330 kg, were each randomly assigned a certain level of CMS (0, 2, 4%) in their diet. The ratio of concentrates to forage in the experimental diets was 22:78, and the cattle were allowed to feed *ad libitum*. The effect of CMS supplementation on weight gain, feed intake, and feed conversion ratio is summarized in Table 8. Total weight gain during the experimental period was highest in the 2% CMS treatment, but there was no significant difference between the treatments ( $p > .05$ ). Daily weight gain was also highest in the 2% supplementation group, but again no significant difference was detected between the treatments ( $p > .05$ ). This result indicates that different levels of CMS supplementation did not affect weight gain in Korea native cattle.

In terms of feed intake and feed conversion ratio, there was no significant difference in feed intake between the treatments ( $p > .05$ ). The feed conversion ratio was highest in the 4% treatment ( $p$

Table 5. Chemical compositions and physical property of Condensed Molasses Fermentation Solubles (CMS)

| Item               |      |
|--------------------|------|
| Moisture, %        | 42.0 |
| Crude protein, %   | 45.0 |
| NPN, %             | 32.0 |
| Crude fat, %       | -    |
| Crude fiber, %     | 1.0  |
| Crude ash, %       | 4.1  |
| pH                 | 6.7  |
| Viscosity          | 28.0 |
| Specific gravity   | 1.28 |
| Freezing point, °C | -40  |

Source: Kim 1993

Table 6. Mineral composition of CMS

| Minerals              | %     |
|-----------------------|-------|
| Calcium               | 0.020 |
| Potassium             | 0.140 |
| Phosphorus            | 0.740 |
| Magnesium             | 0.080 |
| Sulfur                | 0.670 |
| Chloride              | 3.040 |
| Manganese             | 0.029 |
| Iron                  | 0.093 |
| Zinc                  | 0.006 |
| Copper                | 0.003 |
| Lead <sup>a</sup>     | 0.359 |
| Cadmium <sup>a</sup>  | 0.037 |
| Chromium <sup>a</sup> | 0.330 |

Source: Kim 1993. a ppm

Table 7. Composition (%) of amino acids in CMS

| Amino acid    | Content |
|---------------|---------|
| Aspartic acid | 1.20    |
| Threonine     | 0.19    |
| Serine        | 0.23    |
| Glutamic acid | 5.52    |
| Proline       | -       |
| Glycine       | 0.24    |
| Alanine       | 1.47    |
| Cystine       | 0.42    |
| Valine        | -       |
| Methionine    | -       |
| Ileucine      | 0.17    |
| Leucine       | 0.24    |
| Tyrosine      | -       |
| Phenylalanine | -       |
| Lysine        | 0.19    |
| Histidine     | -       |
| Arginine      | -       |
| Total         | 9.98    |

Source: Kim 1993

< .05), and lowest with the smallest intake.

Overall, weight gain was highest at a 2% level of CMS supplementation. However, feed intake was highest and weight gain lowest in the 4% treatment group.

Economic analysis (Table 9) showed that gross income was highest in the 2% treatment group ( $p > .05$ ), since feed costs were lowest in that treatment ( $p < .05$ ). Income from the 2% treatment group was higher than that of the 4% treatment group by US\$1.01/day/head. Consequently, CMS supplementation is more economical at 2% than at 4%.

Feeding high-energy diets with good-quality nutrients is essential for high-yielding dairy cattle. CMS not only contains high levels of good-quality protein, but it has a pleasant flavor from the fermentation of molasses, and is now being utilized in the diet of beef cattle (Wagner *et al.* 1983; De Haan 1973). However, little information is available about the effect of CMS on lactating dairy cows.

A study was performed to investigate the effects of different levels of CMS on the milk yield of dairy cattle. Fifty-four Holstein cows, all with similar calving intervals, lactation periods and milk yields, were randomly treated with different levels of CMS (0, 2, 4%) as part of a complete mixed ration for lactating dairy cattle (NRC 1972).

As Table 10 shows there was no significant difference between the treatments with regard to milk yield at 4% FCM ( $p > .05$ ), nor were these any

significant differences in milk quality ( $p > .05$ ). Consequently, this study suggests that up to 4% CMS may be used as a supplement in the diet of lactating dairy cattle.

#### ***Fermented Soybean Paste Residue***

A major by-product of the sauce industry in Korea is fermented soybean paste residue. This is produced after soy sauce has been extracted from soybean paste under pressure. The chemical composition of the paste residue is shown in Table 11. As with CMS, most of the paste residue is wasted and very little is utilized on farms, even those located near soy sauce plants. However, Korea is now focusing its attention on its unutilized feed resources. We can expect a number of studies on the use of fermented soybean paste residue for livestock feed to be conducted in the near future.

### **BY-PRODUCTS FROM FRUIT AND VEGETABLE PROCESSING**

By-products of citrus processing are a major concern in Korea, where large amounts of citrus are produced, particularly on Jeju island, in the south of Korea. The main by-product of citrus processing is citrus pulp.

#### **Citrus Pulp and its Nutritive Value**

Citrus pulp consists of 60-65% peel, 30-

Table 8. Effects of CMS on growth performance in Hanwoo (Korean native cattle)

| Item                    | CMS (%) |        |         |
|-------------------------|---------|--------|---------|
|                         | 0       | 2      | 4       |
| Initial body weight, kg | 329.37  | 322.71 | 339.25  |
| Final body weight, kg   | 377.50  | 374.13 | 385.54  |
| Total gain, kg          | 48.13   | 51.42  | 46.29   |
| Daily gain, kg          | 1.09    | 1.17   | 1.05    |
| Daily feed intake, kg   | 9.35    | 9.32   | 9.53    |
| Total feed intake, kg   | 411.4   | 410.08 | 419.32  |
| Feed conversion ratio   | 8.28    | 7.37   | 9.31    |
| Crude protein intake, g | 981.0   | 892.5  | 1,094.2 |
| Crude fat intake, g     | 180.3   | 160.4  | 203.7   |

Source: Ha 1993

Table 9. Economical analysis of the use of CMS in feed for beef cattle (Korean native cattle)

| Item                   | CMS (%) |        |       |
|------------------------|---------|--------|-------|
|                        | 0       | 2      | 4     |
| Gross income, US\$     | 7.22    | 7.72   | 6.95  |
| Concentrate cost, US\$ | 0.85    | 0.74   | 0.91  |
| Rice straw cost, US\$  | 0.22    | 0.19   | 0.27  |
| Income, US\$           | 6.15    | 6.77   | 5.76  |
| Income index           | 100.00  | 110.16 | 93.68 |

Source: Ha 1993

Table 10. Effects of CMS on lactating dairy cows

| Item                          | CMS (%) |       |       |
|-------------------------------|---------|-------|-------|
|                               | 0       | 2     | 4     |
| Milk yield, kg/day            | 18.60   | 18.20 | 18.18 |
| 4% fat corrected milk, kg/day | 16.50   | 16.50 | 15.93 |
| Fat, %                        | 3.48    | 3.62  | 3.40  |
| Protein, %                    | 3.14    | 3.23  | 3.10  |
| Lactose, %                    | 4.93    | 4.73  | 4.79  |
| Non-fat solids %              | 8.79    | 8.68  | 8.62  |

Source: Shin 1993

35% pulp, and 0-10% seeds. On average, citrus pulp represents 60% of the fresh weight, with a mean dry matter content of 19.7% (Pascual and Carmona 1980).

There are around 7,000 citrus farms on Jeju island, producing a total of 800 thousand mt of citrus each year. Of this, about 180 thousand mt is processed, producing 80 thousand mt of by-products.

Citrus pulp contains 10.8 - 12.7% crude fiber, 8.3 - 9.7% crude protein, 59.3 - 69.5% nitrogen free extract, and 62.8 - 76.1% total digestible nutrients, which make the pulp a promising energy source for livestock. In addition, the relatively high level of crude fiber makes it a possible feed source for ruminants.

Citrus pulp is now mainly discarded as waste, and is seldom used as ruminant feed. However, a decline in domestic feed resources and the need for Korea's livestock production to become internationally competitive are strong reasons for the greater utilization of by-products, including citrus pulp. The following section discusses the utilization of citrus pulp as a livestock feed in Korea (Table 12).

## Utilization of Citrus Pulp in Korea

### Cattle

A study (Jeju Experiment Station 1991) was conducted to determine whether the use of citrus pulp could reduce the amount of concentrates needed by lactating dairy cows. As Table 13 shows, replacing 30% of concentrates with citrus pulp did not affect either the milk yield or the milk fat content. The results of this study clearly indicate that citrus pulp might replace a considerable part of the concentrates in the diet of lactating dairy cows.

However, the high water content of citrus pulp, and the fact that it is available for only three months a year, are major constraints in converting citrus pulp into a livestock feed. To solve these problems, the pulp could be made into silage. It contains high levels of NFE (nitrogen free extract), which can be a good substrate for fermentation.

Park (1981) conducted an experiment to investigate the effect of citrus pulp silage on the *in vitro* production of volatile fatty acids (VFA). In this

study, citrus peel, citrus pulp and wilted citrus pulp were compared with silage made from citrus pulp combined with 10% wheat bran, 18% rice straw and 10% grass, in terms of their effect on *in vitro* levels of lactic acid, volatile fatty acids, and dry matter digestibility (Table 14). The production of lactate was highest in the group using citrus peel. However the ratio of production of total acid to lactic acid was highest in the treatment using wilted citrus pulp. The Flieg's score and dry matter digestibility were also considerably higher in the wilted citrus pulp. This study indicates that a lower water content of citrus pulp might affect both the *in vivo* production of organic acids, and nutrient digestibility.

Two experiments (Park 1981, Oh 1981) have been carried out to determine the appropriate level of citrus pulp silage in the diet of fattening cattle. Results indicated that cattle fed 20% citrus pulp silage had the same total and daily average weight gains as the control, while the group given

40% citrus pulp silage had a lower weight gain (Table 15). Therefore, 20% citrus pulp silage is an appropriate level to use as a partial replacement for feed concentrates.

### Swine

Yang and Chang (1985) investigated the effect of different levels of dried citrus pulp on the growth performance and carcass quality of growing-finishing pigs. In this study, 24 growing-finishing pigs weighing an average of 30 kg were given a supplement of dried citrus pulp at a level of 0, 5, 10 or 15% for 76 days. The results are presented in Table 16 and Table 17. The weight gain and feed intake tended to increase with up to 10% of dried citrus pulp in the diet. In addition, dried citrus pulp clearly improved carcass quality by increasing meat content and carcass length, and reducing back fat.

Table 11. Chemical composition and TDN (%) of fermented soybean paste residues

| Item                  | Dry matter         | Crude protein | Crude fat | Crude fiber | Crude ash | Nitrogen free extract (NFE) | Total digestible nutrients (TDN) |       |
|-----------------------|--------------------|---------------|-----------|-------------|-----------|-----------------------------|----------------------------------|-------|
|                       |                    |               |           |             |           |                             | Cattle                           | Swine |
| Soybean paste residue | 59.40 <sup>1</sup> | 18.00         | 5.10      | 9.30        | 9.90      | 17.10                       | 39.24                            | 36.06 |
|                       | 100 <sup>2</sup>   | 30.30         | 8.59      | 15.66       | 16.67     | 28.79                       | 66.06                            | 60.70 |

Source: Composition of Korean Feedstuffs

1) Fresh form

2) Dried form

Table 12. Chemical composition and total digestible nutrients (%) of citrus pulp

| Item                                | Citrus pulp |          |
|-------------------------------------|-------------|----------|
|                                     | Fresh form  | Dry form |
| Dry matter                          | 85.36       | 100.00   |
| Crude protein                       | 8.25        | 9.66     |
| Crude fat                           | 3.78        | 4.43     |
| Crude fiber                         | 10.82       | 12.68    |
| Crude ash                           | 3.17        | 3.71     |
| NFE                                 | 59.34       | 69.32    |
| Total digestible nutrients (cattle) | 76.15       | 89.21    |
| Total digestible nutrients (swine)  | 62.77       | 73.53    |

Source: Composition of Korean Feedstuffs

Table 13. Effect of dried citrus pulp on the milk yield of dairy cows

| Item                         | Concentrates + silage | Silage as part of total mixed rations | Citrus pulp as 30% of total mixed rations |
|------------------------------|-----------------------|---------------------------------------|---|
| <b>Daily feed intake, kg</b> |                       |                                       |   |
| Concentrates                 | 9.0 (7.90)            | 9.6 (8.39)                            | 9.4 (8.22)                                |
| Silage                       | 19.9 (3.79)           | 26.4 (5.03)                           | -   |
| Citrus pulp                  | -                     | -                                     | 24.3 (4.93)                               |
| Hay                          | 4.7 (4.14)            | 3.8 (3.35)                            | 3.7 (3.29)                                |
| <b>Milk yield</b>            | <b>16.39</b>          | <b>17.941</b>                         | <b>6.92</b>                               |
| <b>Milk fat, %</b>           | <b>3.50</b>           | <b>3.62</b>                           | <b>3.58</b>                               |

Jeju Experiment Station, Korea, 1991

### **Poultry**

Several studies have examined the possibility of utilizing citrus by-products for poultry (Yang and Chung 1985) (Table 18). One experiment studied the effect of citrus peel and pulp in the diet of broiler chicks. Their weight gain and feed intake tended to fall as the level of citrus increased. However, citrus peel which had been heated and dried could replace 5% of the conventional diet for broiler chicks.

Yang and Chung (1985) conducted a similar experiment, using laying hens. The results showed that egg production, weight, and feed intake did not change significantly when 5 and 10% dried peel were added, but that there was a decline in egg production and feed intake when 15% was added to the diet (Table 19). Overall, the results imply that citrus by-products can be utilized, not only for ruminants, but also for monogastric animals. However, more information is needed on what levels and types of citrus by-products are best to use.

### **By-Products of the Food Industry**

Although Korea is a small country, its population density is one of the highest in the world. Therefore, the total consumption of human food is extremely high in relation to the area. This makes it very important that food processing by-products be used as livestock feed.

Each year 720 thousand mt of wheat flour are processed in Korea to make instant noodles, while 300 thousand mt are used to make bakery products. Each of these generates 2,000 mt of by-products each year.

Another common by-product from the food industry is tofu (soybean curd) wastes.

The chemical composition and TDN (total digestible nutrients) of some major by-products from food processing are shown in Table 20. Many of them contain high levels of nitrogen-free energy, particularly those from instant noodles and bakery products, providing a good energy source for livestock. Tofu residues contain relatively high levels of crude protein and fiber.

Even though these by-products have a high enough nutritive value to be valuable livestock feed, most of them are being buried as wastes. There is an urgent need for more studies on how to utilize them efficiently for livestock production.

### **By-Products from Medicinal Herbs**

Most Asian countries, including Korea, utilize large quantities of medicinal herbs. The annual production of medicinal herbs in Korea is estimated to be more than 30 thousand mt. After the extraction of the solubles from medicinal herbs, a residue is left known as "medicinal herb meal".

Among medicine herbs, Korean ginseng is well known for its positive effects on growth, high blood pressure, stress and cancer (Joo 1982), even if the exact mode of action has not been elucidated. After the solubles have been extracted with solvents such as water or alcohol (70-75%), a residue is produced, known as ginseng meal. Approximately 500 mt of ginseng meal are produced each year. Its chemical composition is shown in Table 21.

As the Table shows, ginseng meal is characterized by high levels of protein (16%). Studies utilizing ginseng meal in the 1970s revealed that it

Table 14. Quality improvement in silage made from citrus by-products, by wilting the peel and using additives

| silage                  | Moisture content | pH  | Organic acid |         |        |        | Lactate / Total | Flieg's Score | <i>In vitro</i> DMD* |
|-------------------------|------------------|-----|--------------|---------|--------|--------|-----------------|---------------|----------------------|
|                         |                  |     | Total        | Lactate | Butyl. | Propio |                 |               |                      |
| Citrus peel             | 80.6             | 3.6 | 4.26         | 2.96    | 1.3    | -      | 69.5            | 88            |                      |
| Citrus pulp             | 86.4             | 3.4 | 2.63         | 1.85    | 0.78   | -      | 70.3            | 88            | 83.8                 |
| Wilted citrus pulp      | 82.4             | 3.5 | 2.23         | 1.82    | 0.41   | -      | 81.6            | 95            | 84.3                 |
| Pulp + wheat bran (10%) | 77.0             | 3.9 | 2.22         | 1.78    | 0.45   | -      | 80.2            | 95            | 77.2                 |
| Pulp + rice straw (10%) | 82.0             | 3.9 | 2.17         | 0.46    | 1.71   | -      |                 | 50            | 59.5                 |
| Pulp + grass (10%)      | 81.9             | 3.9 | 1.88         | 0.59    | 1.25   | 0.03   |                 | 45            | 50.5                 |

Source: Park *et al.* 1981

\*DMD: Dry matter disappearance.

Table 15. Effect of citrus pulp on feed intake and growth performance of fattening cattle\*

| Item                                  | Park <i>et al.</i> (1981) |      |      | Oh <i>et al.</i> (1981) |      |      |
|---------------------------------------|---------------------------|------|------|-------------------------|------|------|
|                                       | Control                   | 20%  | 40%  | Control                 | 20%  | 40%  |
| Initial weight, kg                    | 210                       | 197  | 204  | 222                     | 217  | 217  |
| Final weight, kg                      | 281                       | 264  | 252  | 266                     | 269  | 252  |
| Weight gain, kg                       | 71                        | 67   | 48   | 44                      | 52   | 35   |
| Daily weight gain, kg of concentrates | 0.78                      | 0.71 | 0.54 | 0.75                    | 0.88 | 0.60 |
| Daily intake, kg*                     | 5.07                      | 5.10 | 5.66 | 3.84                    | 5.72 | 8.53 |
| Daily silage intake, kg               | 4.34                      | 3.44 | 4.34 | 7.35                    | 7.36 | 7.28 |
| Daily hay intake, kg                  | 1.91                      | 2.12 | 2.08 | 0.99                    | 0.99 | 0.98 |

\* 0, 20 and 40% concentrates were replaced with citrus pulp silage in Park (1981) and 0, 20, 40% wheat bran in concentrates were replaced with citrus pulp silage in Oh (1981). All values were converted to an air dry matter basis.

increased the milk yield and milk quality of dairy cattle (Joo 1979), and also the growth rate of chicks (Kim 1976).

Recently, Maeng and his coworkers (1994) have conducted a study to evaluate the effects of supplements of ginseng meal in alfalfa hay on rumen fermentation. Basal diets in which alfalfa hay had been partially replaced with different levels of ginseng meal (0, 5, 10, 15%) were fermented *in vitro* with ruminal contents for 48 hrs. Table 22 and Table 23 show the results of this study.

In terms of *in vitro* dry matter digestibility, supplementary ginseng meal did not make any significant improvement during the 48 hr. incubation period. Moreover, it reduced *in vitro* crude protein digestibility, which showed a significant decrease after 48 hours' incubation ( $P < .05$ ). A supplement of

ginseng meal did tend to increase the production of volatile fatty acids, but not to any significant extent.

This study did suggest that ginseng meal could be used as a feed resource for ruminants, although its feed efficacy is somewhat lower than that of alfalfa hay. Economic analysis might therefore be a suitable topic to study, in this context.

One characteristic of ginseng meal is that it contains mysterious components such as saponin and its derivatives, which are generally believed to be active medical ingredients. Interestingly enough, some livestock farmers raising Korean native cattle feed them medicinal herbs, including ginseng meal, to improve the carcass quality. This may be one way of raising the international competitiveness of Korean beef producers.

Table 16. Effect of dried citrus peel on feed intake and growing performance in growing-finishing pigs

| Item                  | Growing period |            |             |             | Finishing period |            |             |             | Whole period |            |             |             |
|-----------------------|----------------|------------|-------------|-------------|------------------|------------|-------------|-------------|--------------|------------|-------------|-------------|
|                       | Control        | Peel<br>5% | Peel<br>10% | Peel<br>15% | Control          | Peel<br>5% | Peel<br>10% | Peel<br>15% | Control      | Peel<br>5% | Peel<br>10% | Peel<br>15% |
| Final weight, kg      | 55.12          | 55.51      | 58.07       | 55.81       | 81.12            | 84.34      | 87.21       | 81.85       | 81.12        | 84.34      | 87.21       | 81.85       |
| Weight gain, kg       | 24.64          | 25.28      | 25.92       | 24.00       | 26.00            | 28.83      | 29.14       | 26.04       | 50.64        | 54.11      | 55.06       | 50.04       |
| Daily gain, kg        | 0.77           | 0.79       | 0.81        | 0.75        | 0.84             | 0.93       | 0.94        | 0.84        | 0.80         | 0.86       | 0.874       | 0.79        |
| Total feed intake, kg | 72.3           | 73.6       | 75.2        | 72.6        | 93.9             | 105.7      | 109.4       | 100.11      | 66.65        | 179.3      | 184.6       | 172.5       |
| Feed intake, kg/day   | 2.26           | 2.30       | 2.35        | 2.27        | 3.03             | 3.41       | 3.53        | 3.23        | 2.64         | 2.85       | 2.93        | 2.74        |
| Feed/gain             | 2.94           | 2.91       | 2.90        | 3.03        | 3.61             | 3.67       | 3.76        | 3.85        | 3.28         | 3.32       | 3.36        | 3.45        |

Source: Yang and Chung 1987

Table 17. Effect of dried citrus peel on the carcass quality of finishing pigs

| Item                                       | Treatment |         |          |          |
|--|-----------|---------|----------|----------|
|  | Control   | Peel 5% | Peel 10% | Peel 15% |
| Live weight                                | 81.16     | 84.34   | 87.21    | 81.85    |
| Carcass weight                             | 61.93     | 66.38   | 69.86    | 64.17    |
| Carcass content, %                         | 76.30     | 78.70   | 80.10    | 78.40    |
| Back fat thickness, cm                     | 3.90      | 3.70    | 2.80     | 2.50     |
| Carcass length, cm                         | 78.80     | 81.40   | 87.30    | 88.10    |
| <i>Longissimus dorsi</i> , cm <sup>2</sup> | 29.80     | 31.60   | 35.90    | 36.10    |
| Cholesterol in back fat, mg/100g           | 539.00    | 545.30  | 442.30   | 408.70   |

Source: Yang and Chung 1985

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Table 18. Effects of dried citrus on growth performance of broiler chicks

| Item                     | Starting period<br>(1 - 3 weeks) |            |             |                          | Final period<br>(4 - 6 weeks) |            |             |                          | Whole period<br>(1 - 6 weeks) |            |             |                          |
|--------------------------|----------------------------------|------------|-------------|--------------------------|-------------------------------|------------|-------------|--------------------------|-------------------------------|------------|-------------|--------------------------|
|                          | Control                          | Peel<br>5% | Peel<br>10% | Peel<br>15%<br>+ Pulp 5% | Control                       | Peel<br>5% | Peel<br>10% | Peel<br>15%<br>+ Pulp 5% | Control                       | Peel<br>5% | Peel<br>10% | Peel<br>15%<br>+ Pulp 5% |
| Initial weight, kg       | 117.2                            | 120.2      | 119.8       | 122.1                    | 820.9                         | 808.3      | 795.3       | 771.0                    | 117.2                         | 120.2      | 119.8       | 122.1                    |
| Final weight, kg         | 820.9                            | 808.3      | 795.3       | 771.0                    | 1952.9                        | 1915.7     | 1829.2      | 1737.0                   | 1952.9                        | 1915.7     | 1829.2      | 1737.0                   |
| Weight gain, g           | 703.5                            | 688.1      | 675.5       | 648.9                    | 1131.6                        | 1107.4     | 1033.9      | 966.0                    | 1835.1                        | 1795.5     | 1709.4      | 1614.9                   |
| Daily weight gain, g/day | 33.5                             | 32.8       | 32.2        | 30.9                     | 53.9                          | 52.7       | 49.2        | 45.1                     | 43.7                          | 42.8       | 40.7        | 38.5                     |
| Feed intake, kg          | 1.35                             | 1.35       | 1.33        | 1.29                     | 3.00                          | 2.97       | 2.92        | 2.76                     | 4.35                          | 4.31       | 4.25        | 4.05                     |
| Daily feed intake, g/day | 64.3                             | 64.1       | 63.4        | 61.3                     | 142.9                         | 141.4      | 139.1       | 131.5                    | 103.6                         | 102.8      | 102.2       | 96.4                     |
| Feed/gain                | 1.92                             | 1.95       | 1.97        | 1.98                     | 2.65                          | 2.68       | 2.82        | 2.86                     | 2.37                          | 2.40       | 2.49        | 2.51                     |

Source: Yang and Chung 1984

Table 19. Effects of dried citrus by-products on laying performance of hens

| Item                     | Control | Peel 5% | Peel 10% | Peel 15% | Pulp 5% |
|--------------------------|---------|---------|----------|----------|---------|
| Hen-day egg prod., %     | 81.7    | 82.5    | 81.7     | 78.9     | 81.4    |
| Hen-house egg prod.      | 113.0   | 112.9   | 113.5    | 103.2    | 110.3   |
| Average egg weight, g    | 62.1    | 61.6    | 61.4     | 59.6     | 61.2    |
| Total feed intake, kg    | 531.2   | 530.1   | 538.3    | 526.3    | 537.6   |
| Daily feed intake, g/day | 128.2   | 129.2   | 129.8    | 127.0    | 128.0   |
| Feed conversion          | 2.52    | 2.54    | 2.58     | 2.70     | 2.55    |

Source: Yang and Chung 1985

Table 20. Chemical composition and total digestible nutrients (%) of human food by-products

| Type of by-product  | Dry                 | Crude matter | Ether protein | Crude extract | Calcium fiber | Nitrogen free extract | Total digestible nutrients |       |
|---------------------|---------------------|--------------|---------------|---------------|---------------|-----------------------|----------------------------|-------|
|                     |                     |              |               |               |               |                       | Cattle                     | Swine |
| Instant noodles     | 89.22 <sup>1</sup>  | 8.02         | 10.0          | 22.07         | 3.38          | 65.66                 | -                          | -     |
|                     | 100.00 <sup>2</sup> | 8.99         | 11.31         | 2.32          | 3.79          | 73.59                 | -                          | -     |
| Bakeries            | 85.31 <sup>1</sup>  | 12.66        | 3.87          | 0.51          | 2.12          | 66.15                 | -                          | -     |
|                     | 100.00 <sup>2</sup> | 14.84        | 4.54          | 0.60          | 2.49          | 77.54                 | -                          | -     |
| Baking powder       | 90.67 <sup>1</sup>  | 8.12         | 11.35         | 1.00          | 6.96          | 63.24                 | -                          | -     |
|                     | 100.00 <sup>2</sup> | 8.96         | 12.52         | 1.10          | 7.68          | 69.75                 | -                          | -     |
| Tofu residues       | 14.50 <sup>1</sup>  | 4.64         | 2.42          | 3.77          | 0.62          | 3.05                  | 12.82                      | 10.52 |
|                     | 100.00 <sup>2</sup> | 32.00        | 16.69         | 26.00         | 4.28          | 21.03                 | 88.39                      | 72.52 |
| Soymeal by-products | 20.76 <sup>1</sup>  | 8.57         | 3.62          | 1.74          | 0.88          | 5.95                  | 19.19                      | 15.93 |
|                     | 100.00 <sup>2</sup> | 41.28        | 17.44         | 8.38          | 4.22          | 28.66                 | 92.42                      | 76.71 |

Source: Composition of Korean Feedstuffs  
1: fresh form, 2: dried form

Table 21. Chemical composition (%) of dried ginseng meal

| Item                    | Content |
|-------------------------|---------|
| Crude protein           | 16.06   |
| Ether extract           | 2.00    |
| Neutral detergent fiber | 45.00   |
| Crude ash               | 2.60    |
| Nitrogen free extract   | 60.00   |

Source: Kim *et al.* 1994

Table 22. Effect of dried ginseng meal on the *in vitro* digestibility of dry matter and protein, and on volatile fatty acid concentration

| Item  | % Ginseng meal | Incubation time (hr) |       |       |        |        |
|---|----------------|----------------------|-------|-------|--------|--------|
|   |                | 0                    | 6     | 12    | 24     | 48     |
| <i>In vitro</i> dry matter digestibility (%)    | Control (nil)  | 40.74                | 41.91 | 48.67 | 57.07  | 62.50  |
|   | 5%             | 38.25                | 43.93 | 46.80 | 58.01  | 60.64  |
|   | 10%            | 31.81                | 40.78 | 47.56 | 58.31  | 59.52  |
|   | 15%            | 30.12                | 39.61 | 42.24 | 56.94  | 60.41  |
| <i>In vitro</i> crude protein digestibility (%) | Control (nil)  | 32.94                | 36.33 | 41.35 | 51.72  | 60.40  |
|   | 5%             | 20.82                | 27.70 | 33.19 | 44.53  | 56.31  |
|   | 10%            | 22.30                | 26.49 | 20.40 | 42.49  | 44.44  |
|   | 15%            | 22.06                | 24.69 | 28.75 | 42.22  | 49.15  |
| Total volatile fatty acids (mM/100ml)           | Control (nil)  | -                    | 38.98 | 87.92 | 218.14 | 275.55 |
|   | 5%             | -                    | 43.58 | 77.14 | 235.87 | 299.27 |
|   | 10%            | -                    | 36.92 | 74.14 | 241.44 | 334.42 |
|   | 15%            | -                    | 43.40 | 69.49 | 211.58 | 308.89 |

Source: Kim *et al.* 1994

Table 23. Effects of roughage source and ginseng meal on *in vitro* digestibility of dry matter and protein

Source: Kim *et al.* 1994