On-site Output Survey and Feed Value Evaluation on Agro-industrial By-products

W. S. Kwak and J. S. Yoon

School of Life Resources and Environmental Sciences, College of Natural Sciences, Konkuk University, Chung-Ju, Chung-Buk, 380-701, Korea

농산업부산물들에 대한 배출 현장 조사 및 사료적 가치 평가

곽완섭·윤정식

건국대학교 자연과학대학 생명자원환경과학부 축산학전공

ABSTRACT

This study was conducted to make on - site survey on the output pattern and utilization situation of 19 by - products selected, to evaluate their nutritional characteristics, to find out a reliable index with which digestion of by - products can be predicted on the basis of chemical compositions analyzed and to diagnose the risk of using book values in the absence of the actual values analyzed for diet formulation. Production and utilization situations of by - products were quite various. Nutritionally, fruit processing by-products such as apple pomace (AP), pear pomace (PP), grape pomace (GP), and persimmon peel (PSP), and bakery by - products (BB) were classified as energy feeds. Soybean curd meal (SCM), animal by - products such as blood (BD), feather meal (FM) and poultry by - products (PB), and activated milk processing sludge (AMS) were classified as protein feeds. Soy hulls (SH), spent mushroom compost (SMC), barley malt hulls (BMH), waste paper (WP) and broiler litter (BL) were classified as roughage. Rumen contents (RC) and restaurant food waste (FW) were nutritionally analogous to complete diets for cattle and swine, respectively. Compared to soybean meal (SBM), BD and FM contained high ($P<0.05$) levels of amino acids and barley malt sprouts (BMS), AMS and FW contained low ($P<0.05$) levels of amino acids. Enzymatic (pepsin) digestibilities of proteinaceous feeds ranged between 99 and 66%. *In vitro* DM digestibility was high ($P<0.05$) in the order of FW, BB, AP, SH, PP, PSP, BMH, BMS, SCM, GP, RC, PB, BL, WP, SMC, AMS, FM and BD. *In vitro* DM digestibility had the highest correlation ($r = 0.68$) with nonfibrous carbohydrate among chemical components. Differences between analyzed values of chemical components and book values were considerable. Caution is required in using book values when large amount of by - products are used in diets.

(**Key words** : By - product, Waste, Feed, Amino acid, Digestibility.)

Ⅰ. INTRODUCTION

The worldwide deficiency of water resources and the rapid increase of human population are promoting the reduced supply of feeds for animals in the future, followed by elevation of internationally traded feed cost. In this point of time, effective use as animal feeds of organic

Corresponding author : W. S. Kwak, School of Life Resources and Environmental Sciences, College of Natural Sciences, Konkuk University, Chung - Ju, Chung - Buk, 380 - 701, Korea.
Tel : 82-043-840-3521 Fax : 82-043-851-8675 E-mail : wsk@kku.ac.kr

agro-industrial by-products may be an important alternative in the aspect of not only the prevention of environmental pollution but also the development of economical feed resources. Its importance will be more emphasized in the countries where land is small or feedstuffs are deficient.

Organic agro-industrial by-products or wastes appear to contain low heavy metals and high organic matter compared to inorganic industrial wastes. Thus when properly processed, they can be effectively used as animal feeds. Many researches related have been conducted for a long time (NRC, 1983; Negi, 1985; Boucque and Fiems, 1988; Hamza, 1989). In recent years, extensive introduction of total mixed rations (TMR) has apparently stimulated researches on effective use of a variety of cheap by - products (Arosemena et al., 1995; DePeters et al., 1997; Bisaria et al., 1997; Mowrey et al., 1999; Abe, 2001).

Accurate information on nutrient composition of by - products is essential for its scientific use as feed. Digestion of by - products needs to be predicted simply from certain nutrient components. Use of book values in the formulation of diets containing by - products may cause poor animal performance and testing was recommended (Belyea et al., 1989; Arosemena et al., 1995).

Accordingly, this study was conducted to make on - site survey on the output pattern and utilization situation of 19 by - products selected, to evaluate their nutritional characteristics, to find out a reliable index with which digestion of by - products can be predicted on the basis of chemical compositions analyzed and to diagnose the risk of using book values in the absence of the actual values analyzed for diet formulation.

Ⅱ. MATERIALS AND METHODS

1. On - site sample collection and preparation

Nineteen by - products, which were used or potentially usable as feeds, were selected and a total of 95 samples were obtained and analyzed to determine their chemical composition. Samples obtained included fruit processing by - products such as apple (*Malus domestica*) pomace (n=4), pear (*Pyrus pyrifolia*) pomace (n=4), grape (*Vitis vinifera*) pomace (n=4, Chung - Buk Apple and Horticulture Agricultural Cooperatives, Chung - Ju, Chung - Buk province) and persimmon (*Diospyros kaki*) peel (n=4, Sang - Ju, Kyung-Buk province), bakery by - products (n=5, Samlip Food Co., LTD, Chung - Buk province), soy processing by - products (Dr. Chung's Food Co., LTD and Shin Gok Food Co., LTD in Chung-Buk province) such as soybean curd meal (n=5) and soy hulls (n=5), spent mushroom (*Pleurotus ostreatus*) compost (n=6, Moon - Kyung in Kyung-Buk province and Chung - Ju in Chung-Buk province), animal processing by - products (HAN NAENG Co., LTD and Sung Shin Co., LTD in Chung - Buk province) such as blood (n=14), rumen contents (n=11), feather meal (n= 2, Halim Co., LTD, Chun-Buk province) and poultry by products (n=2, Halim Co., LTD, Chun-Buk province), activated slaughterhouse sludge (n=3, Sung Shin Co., LTD, Chung - Buk province), activated milk processing sludge (n=4, KONKUK Milk in Chung - Buk province and Pasteur Milk Co., LTD in Kangwon province), brewery by - products (THE HITE, Chun - Buk province) such as barley malt sprouts (n=3) and barley malt hulls (n=3), waste paper (n=4, city hall and Konkuk University, Chung - Ju), food waste (n=6, Konkuk University cafeteria, Chung-Ju) and broiler litter (n=6, Chun - Buk and Chung - Buk provinces). The number of samples for each by - product varied because in some cases sufficient samples were not available. On - site survey was made on the output pattern and recycling situations of by - products.

2. Laboratory analyses

In preparation for chemical analysis, all samples were stored at －20℃, dried and ground to pass through a 1 mm screen using a Sample Mill (Cemotec, Tecator, Sweden). Dry matter (DM) was determined by drying samples at 105℃ for 24 hours to constant weight and at 60℃ for 48 hours for broiler litter. Crude protein (CP, N × 6.25) and ether extract (EE) were determined by AOAC(1990) method. Crude ash was determined by heating samples at 600℃ for 3 hours. Ash free neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to the method of Van Soest et al. (1991). Hemicellulose was calculated as NDF-ADF. Nonfibrous carbohydrate (NFC) was calculated as 100－(NDF + CP + EE + ash). Calcium was assayed by atomic absorption spectrophotometry (SpectraAA-300A, Varian Techtron, USA) using the procedure of AOAC (1990). Phosphorus was analyzed by the method of Fiske and Subbarow (1925). The chemical composition of by - products was presented in Table 1 and 2. Essential and non - essential amino acids of by - products were analyzed with Amino Acid Analyzer (Pharmacia Biotech, England). Pepsin digestibility of proteinaceous by - products was determined by AOAC (1990) method. Digestibility was determined *in vitro* using rumen fluid according to the method of Tilley and Terry (1963). Triplicated samples were incubated for 48 hours. Comparisons were made between chemical values of by - products analyzed and values reported by KSFC (1988) and NRC (1988).

3. Statistical analyses

Data were analyzed with GLM procedures and means were compared with Tukey's multiple range test using Statistix7 (2000). Pearson correlations were examined between *in vitro* DM digestibility and chemical components (Statistix7, 2000).

Ⅲ. RESULTS AND DISCUSSION

1. Production and utilization situations of by - products

Fruit processing by-products such as apple, pear and grape pomaces are released from juice manufacturing process and their production was very seasonal and concentrated mostly in winter. Apple, grape and pear pomaces were composed of peel, core and pulp. Apple or grape pomace was generated at about 10% level of the total processed amount and pear pomace at less level. Production of apple pomace was the highest among them. These fruit processing by - products were transported to feed mills, dehydrated and used as animal feed. For persimmon peel, its production was also very seasonal and concentrated mostly in fall. After sun drying, most of it has been burnt. For its potential use as feed, a feeding trial to chickens is being conducted in Kyung - Buk province (Personal communication: S. M. Lee).

Bakery by - products were generated at about

16% level of total bakery production. During winter and vacation seasons, its production tended to reduce due to decreased consumption. Soybean curd meal was generated from soybean curd or soy oil manufacturing processes. The inedible excess was steam - dried and used mostly as dairy feed.

Spent mushroom compost was composed mostly of gin trash (or cottonseed hulls or beet pulp), saw dust (or rice straw) and inoculants. Most of it has been used as fertilizer; however, a research for use as feed was under planning.

For animal processing by - products, which comes from slaughterhouses, blood of cattle and swine was mixed together and released. Blood was either mixed with other materials for composting or vacuum - dried for feeding. Sometimes it could be cooked by steaming in order to facilitate the long distance transportation and storage. Cattle or swine viscera were mostly exported for food to other countries in Asia. Dewatered rumen contents were used as either feed or fertilizer after processing. Sometimes blood was blended into it. For poultry by - products, 15.8 and 13.2% of carcass weight were broiler offal and feathers, respectively. These by - products were dehydrated and used as feed mostly for chicken, dog or fish.

Activated slaughterhouse sludge, which is microbial activated sludge of digestive contents, blood, hair and wash water, was incinerated or used as fertilizer after processing. Activated milk processing sludge, which is microbial activated sludge of spilt milk and wash water, was used mostly as fertilizer. Each of two plants surveyed generated an average of more than 50 metric tons per month.

For other industrial by - products, barley malt sprouts and barley malt hulls from beer companies were produced at 2 to 1 ratio and used as feed. Waste paper released from schools and city hall, which was mostly composed of office paper and newspaper, was incinerated. Its monthly production rate was pretty variable. The total production of broiler litter in Korea was calculated to be about 0.5 million tons in 1998. It has been used mostly as fertilizer and only partly as a feed ingredient of total mixed rations for cattle. Food waste was generated at the level of about 4.2 million tons in 2000. Its recycling rate was approximately 55%, of which more than 60% was used as feed and about 35% as fertilizer (Chung, 2001). Our recent unpublished study with food waste revealed that restaurant source was superior to sources of hospital and apartment complex in feed value.

2. Chemical composition of by - products

For chemical characteristics of fruit and food processing by - products (Table 1), dewatered fruit processing by - products contained 70 to 85% of moisture. Content of OM was very high (96 to 98%) due to very low levels (2 to 4%) of crude ash. Content of EE was 3.4 to 5.9%. Crude protein was at 4% levels and that of grape pomace was about double to that of others. Content of NFC was high and contents of fiber (NDF, ADF) were low in the order of apple pomace, persimmon peel, pear pomace and grape pomace. Hemicellulose content ranged from 5 to 17%. Calcium contents, which ranged from 0.08 to 0.2%, were an average of 2.8 fold as much as P contents, which ranged from 0.02 to 0.08%. In general, among fruit processing by-products, apple pomace contained the highest level of NFC and the lowest level of fiber. Grape pomace was relatively high in EE

Table 1. Chemical characteristics (DM basis) of fruit and food processing by-products[1)]

Item[2)]	AP	PP	GP	PSP	BB	SCM	SH	SMC
	················	················	················	······· % ·······	················	················	················	················
Dry matter	15.0 ±0.1	20.0 ±0.4	30.3 ±6.0	24.2 ±0.2	93.1 ±0.1	17.8 ± 0.5	94.8 ±0.2	74.0 ±1.0
Organic matter	98.1 ±0.3	97.9 ±0.2	97.9 ±0.6	96.1 ±0.3	98.1 ±0.2	96.0 ± 0.1	95.4 ±0.1	83.4 ±3.3
Ether extract	4.8 ±0.7	4.7 ±0.1	5.9 ±2.0	3.4 ±0.47	4.6 ±4.7	10.9 ± 6.9	1.0 ±0.2	1.2 ±0.1
Crude protein	4.6 ±0.2	4.3 ±0.1	8.8 ±0.2	4.5 ±0.1	11.7 ±1.6	30.5 ± 5.8	10.7 ±0.3	12.6 ±1.2
Nonfibrous carbohydrate	53.2 ±0.5	32.9 ±1.3	29.3 ±0.7	47.0 ±1.3	79.9 ±4.9	9.7 ±11.1	12.1 ±0.6	11.8 ±3.2
Neutral detergent fiber[3)]	35.5 ±0.4	56.0 ±0.7	53.9 ±5.2	41.2 ±1.3	1.9 ±0.6	44.9 ±17.0	71.6 ±3.5	57.3 ±6.2
Acid detergent fiber[3)]	30.6 ±1.3	39.1 ±0.5	49.2 ±6.6	31.2 ±1.1	4.0 ±0.7	23.8 ± 2.0	50.1 ±0.9	51.4 ±4.8
Hemicellulose	4.9 ±0.1	16.9 ±0.6	4.7 ±5.3	10.0 ±0.9	–	21.1 ± 3.4	21.5 ±1.3	5.9 ±5.2
Crude ash	1.9 ±0.3	2.1 ±0.2	2.1 ±0.6	3.9 ±0.3	1.9 ±0.3	4.0 ± 0.3	4.6 ±0.1	16.6 ±3.3
Calcium	0.12±0.02	0.08±0.01	0.20±0.01	0.17±0.02	0.08±0.04	0.34± 0.02	0.51±0.03	2.07±0.05
Phosphorus	0.05±0.01	0.05±0.01	0.02±0.01	0.08±0.01	0.07±0.01	0.42± 0.01	0.08±0.02	0.17±0.02

1) AP = apple pomace; PP = pear pomace; GP = grape pomace; PSP = persimmon peel; BB = bakery by-products; SCM = soybean curd meal; SH = soy hulls; SMC = spent mushroom compost.

2) Mean±standard deviation.

3) On ash free basis.

(especially 10.9% in grape seeds) and CP contents, and even in ADF. These chemical characteristics of apple pomace and grape pomace were similar to those reported in NRC (1988, 1998). Pear pomace contained a little high EE and low CP and ash compared to values in NRC (1983).

For food processing by - products, bakery by-products were characterized by an energy source containing low ash (Ca and P) and very high NFC. EE content was variable and high in bakery source (12.8%) and low in bread source (1.0%). For soybean curd meal and soy hulls produced from soy processing plants, the former, which had remarkable differences in chemical composition depending upon generation sources, was especially high in protein. Soy hulls are a roughage source of high fiber. Spent mushroom compost is also a roughage source of high fiber and ash (especially Ca).

For animal processing by-products (Table 2), blood was high in moisture (76%) and dried one was extremely high in protein and low in Ca. Rumen contents were low in NFC and high in fiber and ash probably due to the rapid microbial fermentation of easily degradable portions in the rumen. Compared to the reports (DM 13.3%, EE 4.2%, CP 14.4%, NDF 63.3%, ADF 41.1%, hemicellulose 22.2%, crude ash 9.7%) in a similar study (El - Yassin et al., 1991), dewatered rumen contents in the present study was very low in moisture and CP contents

Table 2. Chemical characteristics (DM basis) of animal processing and other industrial by-products[1)]

Item[2)]	BD	RC	FM	PB	ASS	AMS
	%					
Dry matter	23.7 ±0.25	32.3 ±2.8	93.3 ±0.1	94.0 ± 0.6	33.2 ±0.9	21.5 ±0.5
Organic matter	96.5 ±0.27	91.8 ±3.6	95.7 ±0.2	90.0 ± 0.2	93.4 ±0.7	70.4 ±0.1
Ether extract	1.2 ±0.37	4.8 ±2.1	18.4 ±0.4	25.4 ± 1.0	1.6 ±0.4	2.4 ±0.4
Crude protein	94.7 ±0.58	10.6 ±1.7	71.9 ±0.1	57.0 ± 2.1	15.9 ±0.5	28.0 ±0.2
Nonfibrous carbohydrate	0.5 ±0.3	9.4 ±4.6	–	–	5.5 ±1.1	25.0 ±3.1
Neutral detergent fiber[3)]	–	67.1 ±4.9	59.9 ±3.2	40.7 ± 1.5	70.4 ±3.3	15.1 ±1.5
Acid detergent fiber[3)]	1.6 ±0.64	44.0 ±5.1	45.5 ±1.0	9.8 ±20.6	35.5 ±0.8	0.6 ±0.2
Hemicellulose	–	23.1 ±5.8	14.4 ±2.6	30.9 ±20.7	34.9 ±1.8	14.5 ±1.4
Crude ash	3.5 ±0.27	8.2 ±3.4	4.3 ±0.2	10.0 ± 0.20	6.6 ±0.7	29.6 ±0.1
Calcium	0.03±0.01	0.93±0.47	2.47±0.14	3.93± 0.20	1.28±0.16	0.69±0.14
Phosphorus	0.13±0.01	0.63±0.10	0.46±0.14	1.93± 0.14	0.45±0.07	0.81±0.09

Item[2)]	BMS	BMH	WP	FW	BL
	%				
Dry matter	96.4 ±0.2	89.4 ±0.3	96.0 ±0.2	18.1 ±3.6	72.0 ±9.6
Organic matter	93.3 ±0.1	91.3 ±0.6	90.9 ±0.1	91.4 ±4.5	83.2 ±3.8
Ether extract	0.7 ±0.1	1.6 ±0.1	0.4 ±0.1	10.9 ±5.7	1.6 ±0.8
Crude protein	32.0 ±1.5	10.8 ±0.8	0.4 ±0.1	20.9 ±7.0	20.9 ±1.2
Nonfibrous carbohydrate	1.7 ±3.4	38.2 ±1.9	2.0 ±0.8	36.1 ±3.0	5.9 ±1.5
Neutral detergent fiber[3)]	58.9 ±3.3	40.7 ±2.9	88.2 ±1.3	24.6 ±3.7	54.8 ±10.9
Acid detergent fiber[3)]	21.1 ±6.0	15.7 ±1.5	78.3 ±0.8	13.7 ±2.9	36.3 ±4.1
Hemicellulose	37.8 ±4.1	25.0 ±2.0	9.9 ±1.5	10.9 ±3.2	18.5 ±6.7
Crude ash	6.7 ±0.1	8.7 ±0.6	9.1 ±0.1	8.6 ±4.5	16.8 ±3.8
Calcium	0.18±0.01	0.15±0.01	0.03±0.01	0.26±0.01	2.25±0.71
Phosphorus	0.66±0.01	0.38±0.01	0.01±0.01	0.44±0.02	1.46±0.30

1) BD = blood; RC = rumen contents; FM = feather meal; PB = poultry by-products; ASS = activated slaughterhouse sludge; AMS = activated milk processing sludge; BMS = barley malt sprouts; BMH = barley malt hulls; WP=waste paper; FW=food waste; BL=broiler litter.

2) Mean±standard deviation.

3) On ash free basis.

and similar in EE and fiber contents to those of the above report. Chemical characteristics of rumen contents seemed to be affected more by diets fed to the slaughtered animals rather than sources of production. Feather meal and poultry by - products were characterized by protein feeds of high fat and ash (especially Ca).

For industrial wastes or by-products (Table 2), activated milk processing sludge was considerably high in CP and NFC compared to activated slaughterhouse sludge. Large variation in crude ash content of activated milk processing sludge was due to different chemicals used in different processing plants. Barley malt sprouts and barley malt hulls released from beer companies were characterized by a protein feed of high fiber and roughage of low protein, respectively. The P level was favorable in both by - products.

Waste paper from offices contained a high level of fiber and very low levels of EE, CP, NFC, Ca and P. Restaurant food waste, which contained balanced nutrients, was nutritionally analogous to complete diets for swine.

Broiler litter released from broiler houses is composed of bedding materials (mostly rice hulls), excreta, spilt feed and feather. Deep-stacked broiler litter was characterized by a roughage source of high protein and high mineral and has been used as an ingredient of complete rations for ruminants.

When classified by chemical components, fruit processing by - products such as apple pomace, persimmon peel, pear pomace and grape pomace were classified into energy feeds, soybean curd meal, animal by - products such as blood, feather meal and poultry by - products, and activated milk processing sludge were classified into protein feeds, and soy hulls, spent mushroom compost, barley malt hulls, waste paper and broiler litter were classified into roughage. Rumen contents and food waste of restaurant source were nutritionally analogous to complete diets for cattle and for swine, respectively.

3. Amino acid composition and pepsin digestibility

Amino acid composition and pepsin digestibility of proteinaceous by - products were presented in Table 3. Compared to soybean meal, blood and feather meal contained high ($P<0.05$) levels of amino acids and barley malt sprouts, activated milk processing sludge and food waste contained low ($P<0.05$) levels of amino acids. Blood and feather meal were high ($P<0.05$) in almost all amino acids with the exception of low glutamic acid and isoleucine for the former and low glutamic acid and lysine for the latter, compared to soybean meal. Blood and barley malt sprouts were favorable supplements of a limiting amino acid, lysine. Amino acid profile (expressed as g per 100 g of total amino acids) of soybean curd meal or food waste was similar to that of soybean meal, with the exception of low lysine content. This fact for food waste agreed with findings by Myer et al. (1999). Crude protein and amino acids contents of soybean curd meal were greatly affected by its sources of production (that is, different processing methods) and were much greater than values reported by Park and Song (1996).

These results can be effectively used in diet formulation program considering optimal requirements of individual amino acids for maximal animal performance.

Pepsin digestibilities of proteinaceous feeds

Table 3. Amino acid composition (%, DM basis) and pepsin digestibility of proteinaceous by-products[1,2)]

Item	BD	FM	BMS	SCM	AMS	FW	SBM[3)]	SE
Essential amino acids[4)]	41.80^{a}	25.55^{b}	8.22^{d}	11.40^{cd}	8.65^{d}	9.89^{cd}	17.39^{c}	1.97
Lysine	6.23^{a}(7.7)	1.81^{b}(2.9)	1.21^{b}(6.0)	0.93^{b}(3.6)	1.01^{b}(5.1)	1.09^{b}(4.6)	2.48^{b}(6.1)	0.42
Threonine	3.63^{a}(4.5)	3.16^{a}(5.1)	0.95^{b}(4.7)	1.22^{b}(4.7)	1.12^{b}(5.7)	1.07^{b}(4.5)	1.55^{b}(3.8)	0.26
Isoleucine	0.60^{a}(0.7)	2.86^{b}(4.6)	0.79^{a}(3.9)	1.14^{ab}(4.4)	0.90^{a}(4.6)	1.03^{a}(4.3)	1.96^{ab}(4.8)	0.23
Valine	6.37^{a}(7.8)	3.96^{b}(6.4)	1.14^{c}(5.6)	1.29^{c}(5.0)	1.27^{c}(6.4)	1.21^{c}(5.1)	1.88^{c}(4.6)	0.22
Leucine	9.55^{a}(11.8)	5.33^{b}(8.6)	1.48^{d}(7.3)	2.28^{cd}(8.9)	1.50^{d}(7.6)	2.01^{cd}(8.5)	3.41^{c}(8.3)	0.36
Histidine	5.46^{a}(6.7)	0.99^{b}(1.6)	0.62^{b}(3.1)	0.94^{b}(3.7)	0.86^{b}(4.4)	0.92^{b}(3.9)	0.99^{b}(2.4)	0.19
Phenylalanine	6.32^{a}(7.8)	3.14^{b}(5.1)	0.91^{d}(4.5)	1.43^{cd}(5.6)	1.21^{d}(6.1)	1.13^{d}(4.8)	2.17^{c}(5.3)	0.24
Arginine	3.66^{ab}(4.5)	4.32^{a}(7.0)	1.13^{c}(5.6)	1.69^{c}(6.6)	0.81^{c}(4.1)	1.43^{c}(6.0)	2.95^{b}(7.2)	0.28
Nonessential amino acids[4)]	39.32^{a}	36.24^{a}	12.01^{c}	14.79^{c}	11.02^{c}	13.79^{c}	23.55^{b}	2.03
Aspartic acid	9.66^{a}(11.9)	5.16^{b}(8.3)	4.26^{bcd}(21.0)	3.37^{cde}(13.1)	2.43^{e}(12.3)	2.76^{de}(11.7)	5.06^{bc}(12.4)	0.43
Serine	4.49^{a}(5.5)	6.11^{b}(9.9)	1.00^{d}(4.9)	1.52^{cd}(5.9)	1.02^{d}(5.2)	1.23^{cd}(5.2)	2.12^{c}(5.2)	0.27
Glutamic acid	8.33^{a}(10.3)	8.18^{a}(13.2)	2.85^{b}(14.1)	4.91^{b}(19.1)	3.17^{b}(16.1)	4.50^{b}(19.0)	8.74^{a}(21.3)	0.72
Proline	3.42^{a}(4.2)	6.55^{b}(10.6)	1.05^{d}(5.2)	1.47^{d}(5.7)	0.83^{d}(4.2)	1.26^{d}(5.3)	2.55^{c}(6.2)	0.22
Glycine	4.25^{a}(5.2)	5.05^{a}(8.2)	1.05^{b}(5.2)	1.27^{b}(4.9)	1.24^{b}(6.3)	1.72^{b}(7.3)	1.84^{b}(4.4)	0.21
Alanine	6.81^{a}(8.4)	3.18^{b}(5.1)	1.25^{c}(6.2)	1.31^{c}(5.1)	1.68^{cd}(8.5)	1.54^{c}(6.5)	1.83^{c}(4.5)	0.25
Tyrosine	2.38^{a}(2.9)	2.02^{ab}(3.3)	0.56^{d}(2.8)	0.94^{cd}(3.7)	0.68^{cd}(3.4)	0.78^{cd}(3.3)	1.41^{bc}(3.4)	0.20
Total amino acids	81.2^{a}(100)	61.8^{b}(100)	20.3^{d}(100)	25.7^{cd}(100)	19.7^{d}(100)	23.7^{d}(100)	40.9^{c}(100)	4.0
Crude protein	94.7^{a}	71.9^{b}	32.0^{d}	30.5^{d}	28.0^{d}	20.9^{d}	44.0^{c}	1.8
Pepsin digestibility	99.3^{a}	78.5^{bc}	76.0^{bc}	88.7^{ab}	66.3^{c}	87.2^{ab}	–	5.7

[1)] BD=blood; FM=feather meal; BMS=barley malt sprouts; SCM=soybean curd meal; AMS=activated milk processing sludge; FW=food waste; SBM=soybean meal.
[2)] Means of two observations.
[3)] Korean standard feed composition tables (1988).
[4)] Values in parentheses are amino acid levels expressed as g per 100 g of total amino acids.
[abcde] Means with different superscripts within the same row differ ($P<0.05$).

ranged between 99 and 66%. They were high ($P<0.05$) in the order of blood, soybean curd meal, food waste, feather meal, barley malt sprouts, and activated milk processing sludge. Pepsin digestibility of feather meal was similar to that reported by Kim et al. (1998). Pepsin digestibility of food waste was obviously higher than that (82.5%) of dehydrated and probably heat - damaged restaurant food waste reported by Myer et al. (1999). Activated milk processing sludge had the lowest pepsin digestibility, predicting its relatively low protein utilization within the animal body.

4. *In vitro* DM digestibilities of by - products

In vitro DM digestibilities of fruit and food processing by - products were ranked as shown in Fig. 1. High (P<0.05) digestibility (76 to 72%) group included bakery by - products, apple pomace and soy hulls. Medium (P<0.05) digestibility (59 to 42%) group included pear pomace, persimmon peel, soybean curd meal and grape pomace. Spent mushroom compost had the lowest (P<0.05) digestibility (18%). The rank of *in vitro* DM digestibility for apple pomace, soy hulls and grape pomace agreed with that of total digestible nutrients values for these by - products reported by Abe (2001) in Japan.

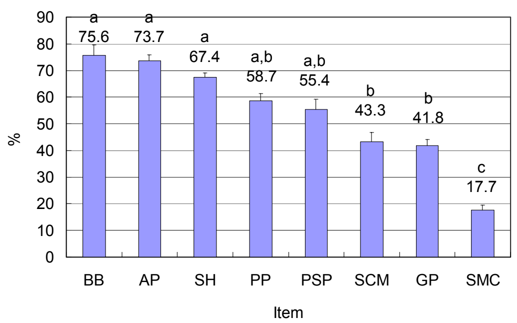

Fig. 1. *In vitro* dry matter digestibilities of fruit and food processing by-products(BB=bakery by-products; AP= apple pomace; SH=soy hulls; PP= pear pomace; PSP=persimmon peel; SCM=soybean curd meal; GP=grape pomace; SMC=spent mushroom compost) [Means with different letters differ (P 〈0.05) and n=3].

In vitro DM digestibilities of animal processing and other industrial by - products were ranked as shown in Fig. 2. *In vitro* DM digestibility was highest (P<0.05) for restaurant food waste. Medium digestibility (54~32%) group included soy hulls, barley malt sprouts, rumen contents, poultry by - products and broiler litter. Low (P< 0.05) digestibility (20~12%) group included waste paper, activated milk processing sludge, feather meal and blood.

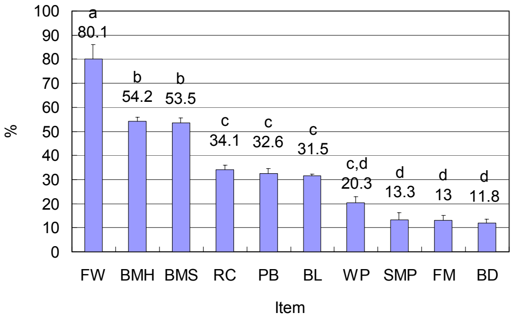

Fig. 2. *In vitro* dry matter digestibilities of animal processing and other industrial by-products (FW=food waste; BMH=barley malt hulls; BMS=barley malt sprouts; RC=rumen contents; PB=poultry by-products; BL=broiler litter; WP=waste paper; AMS=activated milk processing sludge; FM = feather meal; BD=blood) [Means with different letters differ (P 〈0.05) and n=3].

Regardless of by - product types, *in vitro* DM digestibility was high (P<0.05) in the order of food waste, bakery by - products, apple pomace, soy hulls, pear pomace, persimmon peel, barley malt hulls, barley malt sprouts, soybean curd meal, grape pomace, rumen contents, poultry by-products, broiler litter, waste paper, spent mushroom compost, activated milk processing sludge, feather meal and blood. The low (P< 0.05) digestibilities of feather meal and blood may be attributed to high contents of undegradable protein (NRC, 1988).

This information may be helpful in predicting bio-utilization of these by-products under practical feeding. Furthermore, it indicates that it will be impossible to make a nutritionally balanced diet with either one of waste paper, spent mushroom compost, activated milk processing sludge, feather meal or blood, alone.

5. Correlation of *in vitro* DM digestibility with chemical components

It has been known that *in vitro* digestibility of feedstuffs was highly correlated with *in vivo* digestibility under practical feeding (Van Soest et al., 1978; Gasa et al., 1989). Organic matter digestibilities of vegetable and fruit by-products were accurately predicted from *in situ* DM disappearance after 48 h incubation (Gasa et al., 1989). In an attempt to predict digestibilities of by-products from chemical components analyzed, correlation between *in vitro* DM digestibility and chemical components was examined and presented in Table 4. For fruit and food processing by-products, *in vitro* DM digestibility had the highest correlation with dietary OM or crude ash (r = 0.76 and r = −0.76, respectively) and the next highest correlation with NFC (r = 0.61).

For animal processing and other industrial by-products, *in vitro* DM digestibility had the highest correlation with NFC (r = 0.60) and relatively low correlation with OM (r = 0.24). The pooled *in vitro* DM digestibility had the highest correlation (r = 0.68) with NFC among chemical components. In contrast to this, although ADF has been used as an index for predicting digestibility of roughage (Van Soest et al., 1978), it was not the case for agro-industrial by-products selected in this study.

These results indicate that NFC may be used as an important index for predicting digestibility of by-products within the animal body. A further study is required to certify its direct correlation with *in vivo* data.

Table 4. Correlation coefficients between *in vitro* dry matter digestibility (IVDMD) and chemical components of by-products[1,2)]

Item	OM	EE	CP	NFC	NDF	ADF	Hemicellulose	Crude ash
Correlation coefficients with IVDMD								
Fruit and food processing by-products	0.76	−0.05	−0.33	0.61	−0.39	−0.49	0.02	−0.76
Animal processing and other industrial by-products	0.24	0.01	−0.44	0.60	0	−0.19	0.38	−0.24
Total	0.53	−0.08	−0.52	0.68	−0.12	−0.15	0.03	−0.52

1) OM = organic matter, EE = ether extract, CP = crude protein, NFC = nonfibrous carbohydrate, NDF = neutral detergent fiber, ADF = acid detergent fiber.

2) Pearson correlation (Statistix7, 2000).

6. Comparison between chemical values analyzed and book values

Comparison and differences between chemical values analyzed and book values were presented in Table 5. Some by-products were omitted from this table, because they were not presented in feed composition tables of KSFC (1988) and

Table 5. Comparison of the chemical composition of by-products analyzed in this experiment relative to book values[1,2)]

Feedstuff	Item	EE	CP	Ash	Ca	P
		…………	…………	%	…………	…………
AP	KSFC	5.9	5.5	4.0	0.15	0.19
	Analyzed	4.8	4.6	1.9	0.12	0.05
	SD[3)]	0.7	0.2	0.3	0.02	0.01
	Difference	1.1	0.9	2.1	0.03	0.14
GP	NRC	7.9	13.0	10.3	0.61	0.06
	Analyzed	5.9	8.8	2.1	0.20	0.02
	SD	2.0	0.2	0.6	0.01	0.01
	Difference	2.0	4.2	8.2	0.41	0.04
BB	KSFC	4.5	14.8	2.5	0.05	0.13
	Analyzed	4.6	11.7	1.9	0.08	0.07
	SD	4.7	1.6	0.3	0.04	0.01
	Difference	−0.1	3.1	0.6	−0.03	0.06
SCM	KSFC	16.7	32.0	4.3	0.41	0.36
	Analyzed	10.9	30.5	4.0	0.34	0.42
	SD	6.9	5.8	0.3	0.02	0.01
	Difference	5.8	1.5	0.3	0.07	−0.06
SH	KSFC	4.7	16.7	6.1	0.16	0.45
	Analyzed	1.0	10.7	4.6	0.51	0.08
	SD	0.2	0.3	0.1	0.03	0.02
	Difference	3.7	6.0	1.5	−0.35	0.37
BD	KSFC	0.2	95.5	3.2	0.06	0.20
	Analyzed	1.2	94.7	3.5	0.03	0.13
	SD	0.4	0.6	0.3	0.01	0.01
	Difference	−1.0	−0.8	−0.3	0.03	0.07
FM	KSFC	4.1	82.6	10.8	0.78	0.25
	Analyzed	18.4	71.9	4.3	2.47	0.46
	SD	0.4	0.1	0.2	0.14	0.14
	Difference	−14.3	10.7	6.5	−1.69	−0.21
PB	KSFC	12.5	54.3	26.2	4.06	0.17
	Analyzed	25.4	57.0	10.0	3.93	1.93
	SD	1.0	2.1	0.2	0.20	0.14
	Difference	0.8	−1.4	1.0	−0.12	−0.19
BMS	KSFC	1.5	30.6	7.7	0.06	0.47
	Analyzed	0.7	32.0	6.7	0.18	0.66
	SD	0.1	1.5	0.1	0.01	0.01
	Difference	0.8	−1.4	1.0	−0.12	−0.19

1) Book values from KSFC(Korean Standard Feeding Council, 1988) and NRC(1988) and values analyzed in this experiment.
2) AP = apple pomace; GP = grape pomace; BB = bakery by-products; SCM = soybean curd meal; SH = soy hulls; BD = blood; FM =feather meal; PB = poultry by-products; BMS = barley malt sprouts.
3) SD = standard deviation of means (n = 3).

NRC (1988). For fruit processing by - products such as apple and grape pomaces, book values were consistently higher than the analyzed values and the difference was great especially for grape pomace. Book values of bakery by-products and soybean curd meal agreed well with actual values with the exception of 21% higher for CP of bakery by - products and 31% higher for EE of soybean curd meal. Soy hulls showed considerable differences.

Among animal processing by-products, differences were great for feather meal and poultry by - products, but not for blood. Barley malt sprouts had little difference except for EE and Ca. In general, the substantial differences between book values and actual values analyzed could be attributed to differences in not only individual by - product itself but also processing methods.

As a result, use of accurate nutrient composition of by - products is essential for scientific animal feeding and its importance will escalate as the proportion of by - products in diets increases.

Ⅳ. IMPLICATION

Our results indicate that almost all the by-products selected in this study had fair to excellent feed values with the exception of relatively low quality of spent mushroom compost and waste paper. By - products already used as animal feed included apple pomace, bakery by - products, soybean curd meal, soy hulls, blood, rumen contents, feather meal, poultry by-products, barley malt sprouts, barley malt hulls, food waste and broiler litter. Especially, food waste has great social concerns for more recycling. By - products, which are not used, but will be possibly used as feed, included pear pomace, grape pomace, persimmon pomace, spent mushroom compost, activated slaughter-house sludge, activated milk processing sludge and waste paper. Some high - moisture by-products needed to be further processed for easy storage and transportation. Using the analyzed chemical values of by products is highly recommended for accurate diet formulation for maximal animal performance, due to their considerable differences from book values. It is required to conduct researches on feeding trials with these by - products and on hygienic safety of fruit processing by - products and activated sludges.

Ⅴ. 요 약

본 연구는 산업체에서 발생되는 총 19종 부산물들의 동물사료로의 활용성을 증대시킬 목적으로 유기성 부산물들의 배출 현장을 방문하여 부산물 발생 및 이용 현황을 조사하고, 각각의 화학적 특성을 평가하고, 분석된 화학적 성분들 중에서 부산물 사료의 동물 소화율을 예측할 수 있는 신뢰성 있는 지표를 발굴하고, 사료 배합비 설계 시 실제 분석치 대신 문헌 성분표상의 수치 이용의 위험성을 진단하기 위해서 실시되었다. 실험 결과, 부산물들의 발생 현황 및 이용 현황은 매우 다양하였다. 부산물들을 영양적 주성분에 따라 분류하였을 때, 과일가공부산물(사과박, 감껍질, 배박, 포도박)과 제과부산물은 에너지 사료에 속하였고, 비지, 동물성 사료(혈액, 우모분, 닭내장), 유가공슬러지는 단백질 사료에 속하였으며, 대두피, 버섯잔사, 맥아피, 폐지, 육계분은 조사료에 속하였다. 반추위내용물과 식당 원 남은 음식물의 영양적 특성은 각각 소 TMR사료와 양돈용 배합사료 성분에 근접하였다. 대두박과 비교해서 아미노산 함량은 혈액과 우모분은 상대적으로

높았고 (P<0.05), 맥아근, 유가공 슬러지, 식당 원 남은 음식물들은 상대적으로 낮았다 (P< 0.05). 단백질 원 부산물사료들의 펩신 소화율은 66~99%의 범위에 속하였다. 부산물 종류에 상관없이 *in vitro* 건물 소화율은 식당 원 남은 음식물, 제과부산물, 사과박, 대두피, 배박, 감 껍질, 맥아피, 맥아근, 비지, 포도박, 반추위 내용물, 가금부산물, 육계분, 폐지, 버섯잔사, 유가공 슬러지, 우모분, 혈액의 순으로 높았다 (P <0.05). *In vitro* 건물 소화율은 화학성분들 중에서 비섬유성 탄수화물과 가장 높은 상관관계 (r = 0.68)를 보였으며, 이는 비섬유성 탄수화물이 부산물 사료들의 소화율 예측 시 신뢰성 있는 지표로 이용될 수 있음을 의미한다. 부산물 사료들의 실제 화학 분석치와 문헌에 제시된 성분표 상의 수치간의 차이는 큰 편이었다. 따라서 동물 사료 내에 다량의 부산물 사료를 이용할수록 동물 생산성의 극대화를 위해서는 실제 분석치의 이용이 필수적인 것으로 사료되었다.

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