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Nutritive Value of Some Agro-Industrial By-products for Ruminants - A Review

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Abstract: Dumping or burning wastes or agro-industrial by-products present potential air and water pollution problems. High-moisture wastes are also difficult to burn. Many by-products have a substantial potential value as animal feedstuffs. Ruminants, especially, have the unique capacity to utilize fibre, because of their rumen microbes. This means that cereals can be largely replaced by these by-products. Consequently the competition between human and animal nutrition can be decreased. Nevertheless, there is an increased cereal supply owing to genetic and management improvement. The utilization of agro-industrial by-products may be economically worthwhile, since conventional feedstuffs are often expensive. However, livestock have historically utilized large amounts of well-known and widely-available traditional by-products such as oil meals, bran, middlings, brewers' grains, distillers' grains, beet pulp and molasses. But less conventional by-products have become available, such as vegetable- and fruit-processing residues, whey and culinary wastes. This review evaluates some of By-products in regard to their characteristics, nutritive value and their digestibility.

Key words: Agro-industrial · By-product · Nutritive value · Digestibility

INTRODUCTION

Nowadays, there is great political and social pressure to reduce the pollution arising from industrial activities. Almost all developed and underdeveloped countries are trying to adapt to this reality by modifying their processes so that their residues can be recycled. Consequently, most large companies no longer consider residues as waste, but as a raw material for other processes. Most by-product feedstuffs (BPF) result from the processing of commercial crops, the food processing industry and the fiber industry. Many BPF would be discarded in landfills if they were not fed to ruminants. By-product feedstuffs in the diets of ruminants support growth and lactation and result in the production of human edible food. Consequently, BPF are becoming increasingly more important in the food and fiber system because they are available for use as livestock feeds at competitive prices relative to other commodities. By-product feedstuffs, which contain little economical value as edible foods for human consumption have become major sources of dietary nutrients and energy in support of milk production and will continue to do so in the future. By-product feedstuffs are important in the food and fiber system, yet little research has characterized individual BPF. The variability in chemical composition of some BPF was recently shown to be significant. Evaluation of by- or waste products for ruminants is in principle no different from evaluation of other feedstuffs, but by-products may have some of the following disadvantages. They are often variable in composition, strictly seasonal and local in production and often contain undesirable contaminants of organic or inorganic origin [1, 2]. Many by-products have a substantial potential value as animal feedstuffs. Ruminants, especially, have the unique capacity to utilize fiber, because of their rumen microbes. This means that cereals can be largely replaced by these by-products. Consequently the competition between human and animal nutrition can be decreased. Nevertheless, there is an increased cereal supply owing to genetic and management improvement. The utilization of agro-industrial by products may be economically worthwhile, since conventional feedstuffs are often expensive. However, livestock have historically utilized large amounts of well-known and widely-available traditional by-products such as oil meals, bran, middlings, brewers' grains, distillers' grains, beet pulp and molasses. But less conventional by-products have become available, such as vegetable- and fruit-processing residues, whey and culinary wastes. An intensive feeding system based on locally available BPF is an alternative promising feeding system to rear ruminants economically. Ruminants

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because of their rumen physiological adaptation can utilize inexpensive BPF to meet their maintenance feed requirements, growth, reproduction and production. Although most By-product feedstuffs have low nitrogen content, more fibre as well as low nutrient density, effective processing can raise their nutritive value. The concept of matching ruminant livestock production with available feed resources has therefore intensified research into more use of crop residues and agro-industrial by products in most countries in the tropics and sub tropics. Of course, by-product utilization for animal production is only one possibility. Other alternatives are their use as fuel or fertilizer, or as a carbohydrate source for microbial fermentation processes. The extent of by-product utilization as a feed ingredient depends on the costs of the conventional feedstuffs, the safety for animal health and the attractiveness of alternative uses. As some raw materials can be used for different production processes, the available amount of the various by-products is difficult to estimate and it is even more difficult to assess the quantity used as animal feed. Various classifications of by-products are possible. By-products divided into two major groups according to the content of moisture and fermentable organic matter. Within each class of by-products with high or low fermentable carbohydrate content, those with high or low moisture content can be identified. By-products can also be divided according to their origin: from the food industry; from the non food industry; crop residues and animal wastes. They are divided according to their origin: milling; starch production; fermentation industry; sugar industry; fruit and vegetable processing; oil industry; wood and paper industry [3, 4, 5, 6].

By-products of the Sugar Industry

Sugar Beet: The main raw materials for sugar production are sugar beet and cane. In the case of sugar beet, soil contamination averages 12.5%, but is largely dependent on the harvesting conditions. During washing, broken beets and beet roots are obtained. They account for 2.5-5% of the beets and are either sold directly to the farmer for animal feeding or mixed with either the cleaned beets or the beet pulp. After extraction of the sugar, pulp is left; it is a valuable feedstuff for ruminants. The pulp can be used as such, with a DM content of 10-12%, or pressed to 20-25% or dried to 88-90% DM. About 5 kg beet pulp DM is obtained per 100 kg sugar beets (Fig. 1). The extracted juice is then purified and crystallized, leaving scums and molasses. Scums are used as soil fertilizer, while molasses are used in animal nutrition, either as such or after mixing with pulp before drying [6, 7, 8].

By-products of Alcohol Production And/or Fermentation Industry

Distilling: Considerable amounts of grain are used in the brewing and distillery industry. A large number of distilled spirits are produced throughout the world. They differ according to: the area of origin (bourbon whisky, U.S.A., cognac, France, schnaps, Germany, Scotch whisky, Scotland, tequila, Mexico, vodka, U.S.S.R., grappa, Italy); the type of raw material used (maize, wheat, rye, barley, oats, milo, buckwheat, potatoes, fruits, grape marc); preparation of the raw materials; proportion of raw materials (a mash for manufacturing bourbon whisky must contain a minimum of 51% maize, but more typical ingredients are 75% maize, 12% rye and 13% barley);

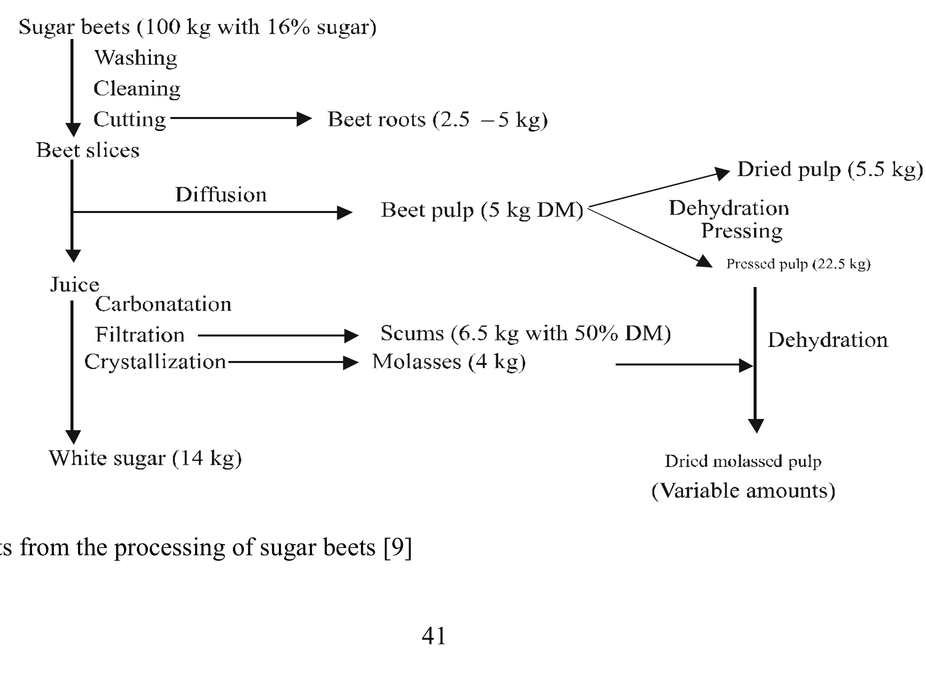

Fig. 1: By-products from the processing of sugar beets [9]

fermentation conditions; distillation processes; maturation processes; mixture techniques. The main by-products are distillers' grains and distillers' solubles. Distillers' solubles are often dried back into the grains, giving distillers' grains with solubles. Approximately 33% of the original dry matter can be recovered in the by-products, 20% in the distillers' grains and 13% in the solubles. This means that 100 kg of grains provides ±33 kg distillers' dried grains with solubles or ±20 kg distillers' dried grains and ±32.5 kg condensed distillers' solubles with ±35% DM. Different production processes can be applied. For instance in Britain the extracted grains and wort are separated after malting while in the U.S.A. the entire mixture is fermented and distilled. Alcohol can also be produced from potatoes. Another source for alcohol production is molasses. A typical alcoholic distillate from the fermentation of cane molasses is rum. Distillation of 100 kg beet molasses yields 40 kg condensed molasses solubles with 65% DM. For cane molasses, only 35 kg condensed solubles are left after distillation. Molasses can also be used as the basic material for other fermentation processes yielding citric acid, yeast, monosodium glutamate, acetic acid, acetone, butanol, lactic acid, glycerol, dextran, aconitic acid and itaconic acid [2, 10].

Brewing: The brewing industry generates relatively large amounts of by-products and wastes; spent grain, spent hops and yeast being the most common. However, as most of these are agricultural products, they can be readily recycled and reused. Thus, compared to other industries, the brewing industry tends to be more environmentally friendly. In the brewing process the initial step involves the malting of barley (Fig. 2). Upon

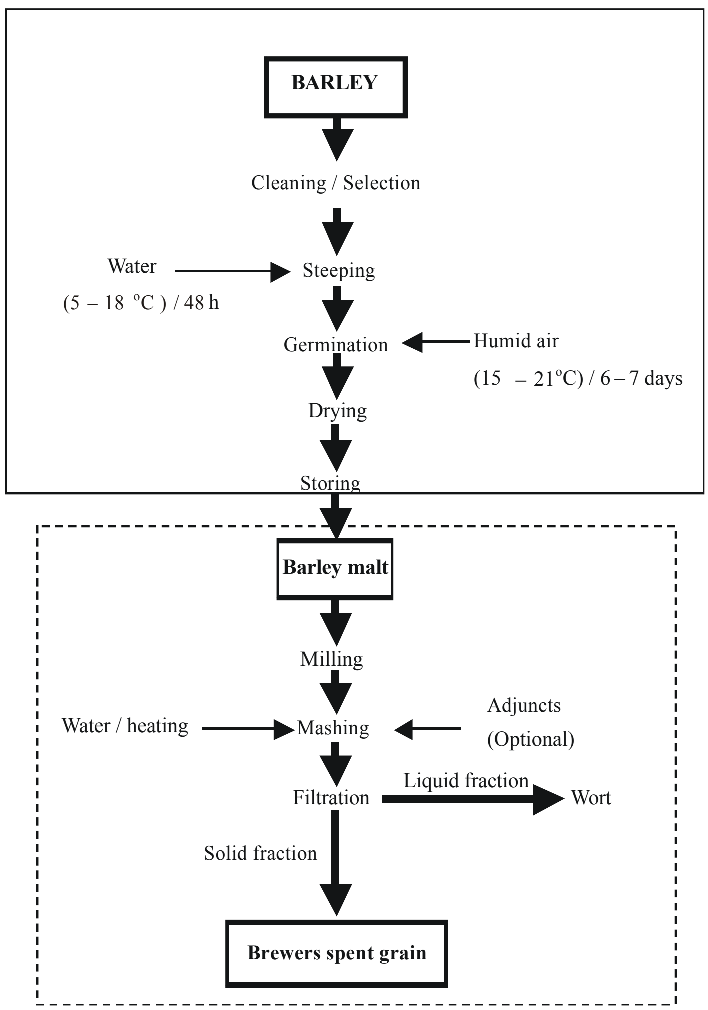

Fig. 2: Schematic representation of the process to obtain BSG from natural barley [11]

germination, the enzymes convert starch to malt sugar. The partially-germinated barley is barley malt. The sprouted barley is dried by heating to stop enzymatic activity. Malt sprouts and malt hulls are then separated. Barley malt is mixed with other grains, generally corn or rice and a flavoring agent, hops, to form a mash. This mash is pressed to give the wort as end-product and brewers' grains as residue. Hops are now joined to the wort. After boiling, the hopped wort is filtered, leaving spent hops as residue. After this step, pure culture yeast is added to the wort and fermentation takes place. The excess yeast then produced is withdrawn, to be known as brewers' yeast. The fermented wort becomes beer. During malting about 10% DM losses occur. Starting with 100 kg barley malt about 3-5% malt sprouts and 110-130 kg wet brewers' grains (±20% DM) are produced. Depending on the economic conditions, brewers' yeast may be sold separately or dried and sold with the grains to yield a mixture of 95% dried brewers' grains and 5% dried brewers' yeast. Dried brewers' grains may also contain 3% dried spent hops. Also the dreg, which amounts to 0.25-0.8% of the malt DM, is often mixed into the brewers' grains. Consequently, this means that the brewers' grains vary in their nutritive value [2, 11].

By-products from Fruits and Vegetables

Citrus Fruits: The extraction of the juice from citrus fruits provides citrus pulp as residue. Citrus pulp consists of 60-65% peels, 30-35% segment pulp and 0-10% seeds. On average citrus pulp represents 60% of the fresh weight with a mean DM of 19.7%, but the residue can range between 49 and 69% of the initial weight. Pressing reduces the moisture to 65-75%. Molasses is then produced from the press liquor. Approximately 3.8 kg molasses may be obtained from 100 kg fresh grapefruit. Afterwards the pulp is dried, but it may also be dried without removing the press liquor. Dehydration of small particles of peel, pulp and seed, which were obtained by sieving the wet residue, provides dried citrus meal. Molasses is sometimes added back to the pulp during the drying process, but can also serve as a fermentation substrate in the beverage-alcohol industry, leaving condensed citrus molasses solubles as residue. There has also been some interest in the separation of the seeds. Citrus seed meal is left after the oil has been extracted from the citrus seeds. The differences in processing, in source and variety of fruit and in type of canning may produce a variation in the physical characteristics and nutritive value of citrus pulp [12, 13, 14].

Apples: Apple pomace is the by-product of the production of cider and juice. It accounts for about 18.5 kg wet or 4.2 kg dried apple pomace per 100 kg apples. Dried apple pomace is a source of pectin. Pectin-extracted apple pomace amounts to 80% of the original dried apple pomace [6, 9, 15].

Grapes: Grape marc is the residue of the wine industry after the juice has been pressed out. The dried marc consists of 40% seeds and 60% pulp. After separating the pulp, the seeds are dried and cleaned. Oil is extracted with hexane, leaving about 85% grape-seed oil meal [6, 9].

Tomatoes: The manufacture of tomato juice and puree provides peels and seeds as residue. They account for about 4.5% of the fresh weight: 3% peels and 1.5% seeds. In some countries, seeds are used for oil production. Following seed pressing or extraction for oil production 73-82% tomato seed oil meal is left as residue. The production of peeled tomatoes provides only peels as residue. Tomato pomace (TP) is a by-product from the processing of tomato paste. After juice is extracted, a residue, wet TP, which is primarily consisting of water, tomato seeds and peels, is left. The high water content (75%) of this byproduct limits its length of storage. Because of storage problems, wet TP is often dried. However, artificial drying increases the price of TP substantially; hence, much of the TP now produced is discarded or fresh fed only limited periods of time. Wet TP would spoil in two days if exposed to the air. Tomato pomace can be fed to ruminant animals for longer periods of time without spoilage, when it is ensiled with or without additives. Addition of grain and straw to TP during ensiling can lower dry matter content of pomace and also eliminate excess water drainage and nutrition losses. Tomato processing by-products can be a valuable energy and nutrient source obtained more cheaply than alternative ingredients to feed ruminants, when it is appropriately preserved [6, 16, 17].

Chemical Composition and Digestibility of By-products: From the previous section it becomes clear that the chemical characteristics of some by-products are very variable, owing to different modes of processing and/or the mixing of different fractions of by-products. In Table 1, we present the mean chemical composition some of by-products (DM basis). Table 2 shows the apparent digestibility coefficients for ruminants. In relation to the energy value of by-products for ruminants,

Table 1: Chemical composition of some agro- industrial by-products (%DM)

By-products	DM (%)	CP	EE	CF	NDF	ADF	Lig	References
Apple pomace								[22, 23, 24, 25, 26]
Fresh	19.6	4.9	3.75	17.7	30.10	25.20	6.4	
Ensiled	18.7	7.2	6.70	22.6	39.20	30.20	9.3	
Beet pulp	87.9	9.2	0.62	20.4	42.20	21.97	1.9	[8, 23, 24, 27, 28]
Brewers dried grains	93.1	28.2	7.10	17.2	54.50	20.10	4.6	[2, 11, 29]
Citrus pulp								[13, 30, 31]
Wet	18.0	6.6	3.30	-	-	-	-	
Dried	89.7	6.9	2.30	-	22.00	19.70	2.1	
Silage	21.0	7.3	9.70	-	-	20.00	-	
Tomato pulp								[16, 17, 23, 24, 32]
Dried	91.3	23.6	8.90	24.1	50.04	36.62	26.7	
Wet	14.2	19.5	12.30	27.3	63.60	43.50	25.8	
Silage	29.5	19.2	14.60	44.9	-	-	-	
Grape marc								[18, 19, 33]
Dried	49.7	13.2	-	-	50.40	-	-	
Silage	22.5	14.4	-	-	69.30	-	-	

DM = Dry matter, CP = Crude protein, EE = ether extract, CF = crude fibre, NDF = Neutral detergent fibre, ADF = Acid detergent fibre, Lig = Lignin

Table 2: Digestibility of some agro- industrial by-products (%)

		Digestibility				
By-products	Animal	DM	OM	CP	NDF	References
Apple pomace						[25, 26]
Fresh	Ewes	-	89.50	-	-	
Ensiled	Cows	-	77.84	-	-	
Beet pulp						[8, 28, 34]
	Cows	63.10	69.50	-	39.1	
Brewers dry grains						[2, 29]
	Cows	43.20	-	48.9	30.1	
Distillery dry grains						[2, 29]
	Cows	44.50	-	39.6	31.2	
Citrus pulp	Withers	-	84.40	50.5	71.0	[13, 23, 24, 30, 31, 34, 35]
	Steers	-	82.60	42.2	69.0	
	Cows	62.90	73.00	-	22.7	
	Sheep	-	83.00	41.1	-	
Tomato pulp						[16, 17, 32]
Dried	steers	35.38	36.53	-	-	
Wet	Sheep	53.81	-	-	-	
Grape marc						[18, 19, 33]
Dried	Buffaloes	34.50	24.70	21.8	18.6	
Silage	Buffaloes	28.50	19.50	-	-	

authors demonstrated that the digestibility of by-products depends on the composition of the basic diet [13, 17, 18, 19]. A variable protein digestibility was also established by Stanhope *et al*. [20]. A lot of by-products are characterized by wide variations in nutrient content. The potential value of by-products in animal feeding depends on their nutritive characteristics, as, the fibrousness, the protein content, organic-matter digestibility and energy value. Palatability is also an important feature. The utilization may not be detrimental for the animal. Apart from the presence of anti-nutritive factors, there are beneficial properties in some by products. For instance, brewers' grains and distillers' grains are effective in controlling liver lipid accumulation in caged layers fed equicaloric, equifat and isonitrogenous corn-soya diets [6, 14, 17, 21].

CONCLUSION

From this overview, we can conclude that there is an extensive list of byproducts. A lot of them, as crop residues, are under-utilized. Environmental problems necessitate the investigation of alternative uses. These can be: animal feed resource, soil fertilizer or fuel. A typical example of different utilizations seems to be grape marc. Future research, mainly via a multi-disciplinary approach, is needed to look for the best use, mainly in terms of economy. However it is not sufficient that a by-product is better suited as an animal feedstuff than for other purposes, but it must also be cheaper than conventional feed ingredients. It also became clear that the chemical composition of by-products can vary largely as a result of different processing methods and materials. The feed manufacturing industry wants raw materials with a constant composition and a regular supply. Therefore simple analytical methods need to be developed for rapid and accurate feedstuff evaluation. Usually, analytical data does not give sufficient information about protein quality, such as true protein and NPN fraction, the protein degradability, the amino-acid composition and organic matter digestibility (OMD). Some by-products have a low nutritive value for animals. If there are still less interesting for other uses, improved utilization can be obtained by heating, steaming, grinding, chemical treatment, radiation, etc.

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