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Effect of Structural Constituents of Cell Wall on the Digestibility of Grape Pomace

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In vitro dry matter digestibility, cell wall digestibility, and chemical composition of cell solubles and cell wall fractions were determined from three grape pomace varieties and two standard feeds. Dry matter digestibility of pomace was low (25-38%) compared to standard feeds. Cell solubles content of pomace is comparable to that of standard feeds but is comprised of organic acids (tartaric and acetic) and pectic polysaccharides. Cell wall digestibility of Cabernet Sauvignon pomace is very low (4%), and lignin + cutin level is very high (29%) compared to standard feeds (34-42% and 6-8%, respectively). The observed digestibility is explained in terms of the structural composition of the cell wall fraction.

Previous investigations have revealed that winery pomace is high in crude fiber and low in digestibility (Folger, 1940; Leonard et al., 1978). Since the nutritional value of a feed depends on its chemical composition, chemical analyses are important in explaining observed nutritional properties of feeds. The detergent system of analysis (Goering and Van Soest, 1970) has been used to quantitatively determine cell wall, cellulose, hemicellulose, and lignin + cutin content of feeds. On the basis of this, digestibilities of forages could be predicted and causatively related (Mowat et al., 1969; Smith et al., 1972; Robbins et al., 1975). From an enological perspective, methods of fractionating grape pulp and skin polysaccharides were developed to provide a better understanding of the biochemistry of wine making (Ezhov and Datunashvili, 1974; Zinchenko et al., 1975; Morgues, 1979). In this report, grape pomace was fractionated with use of modifications of both extraction techniques. Some of these fractions were chromatographically analyzed, and the information obtained is used to explain the observed low in vitro digestibility figures.

MATERIALS AND METHODS

Grape Pomace Varieties. Cabernet Sauvignon (CBS), Gewurztraminer (GWZ), and Tinta Madeira (TMD) were obtained fresh from wineries in Northern California. The seeds were manually removed and the skins dried in a blown-air oven at 60 °C for 48 h and ground in a Willey mill fitted with a 1-mm screen.

Standard Feeds. Alfalfa hay mixed with grain and Sudan grass hay were obtained from the Nutrition Laboratory of the Animal Science Department of UCD.

In Vitro Dry Matter Digestibility (IVDMD). This was determined by the two-stage technique of Tilley and Terry (1963) using rumen fluid obtained from cow, sheep, or goat.

In Vitro Cell Wall Digestibility (IVCWD). This was determined as above, but the starting material was the cell wall fraction, obtained by refluxing the feed in neutral detergent solution.

Detergent extraction was performed according to the method of Bailey and Ulyatt (1970), incorporating sequential analyses (Figure 1). Grape skin polysaccharides were fractionated according to Figure 2.

Analysis of Fractions. Uronide content was determined with *m*-hydroxybiphenol (Ahmed and Labavitch, 1977). Organic acids were determined by high-pressure liquid chromatography (Heymann, 1980), and neutral sugars were determined by gas-liquid chromatography according to Ahmed and Labavitch (1980).

RESULTS AND DISCUSSION

All the pomace samples had low IVDMD compared to the standard feeds (Table I). CBS pomace had higher digestibilities than the other pomace varieties irrespective of the source of rumen fluid, but it was still about 30% lower than the standard feeds. CBS pomace was favored over the others because the grapes are uniformly treated in all wineries, resulting in a pomace of

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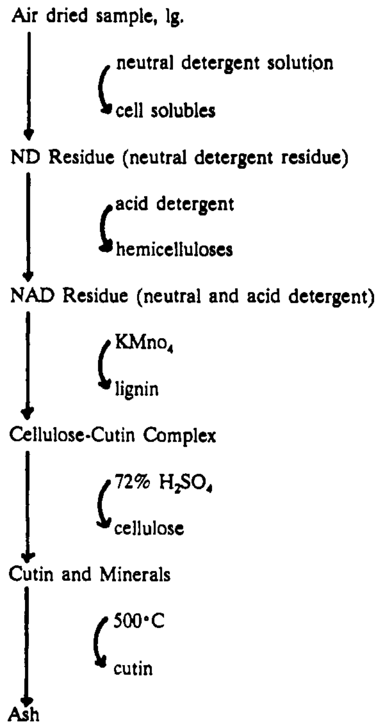

Figure 1. Flow diagram for sequential detergent analysis.

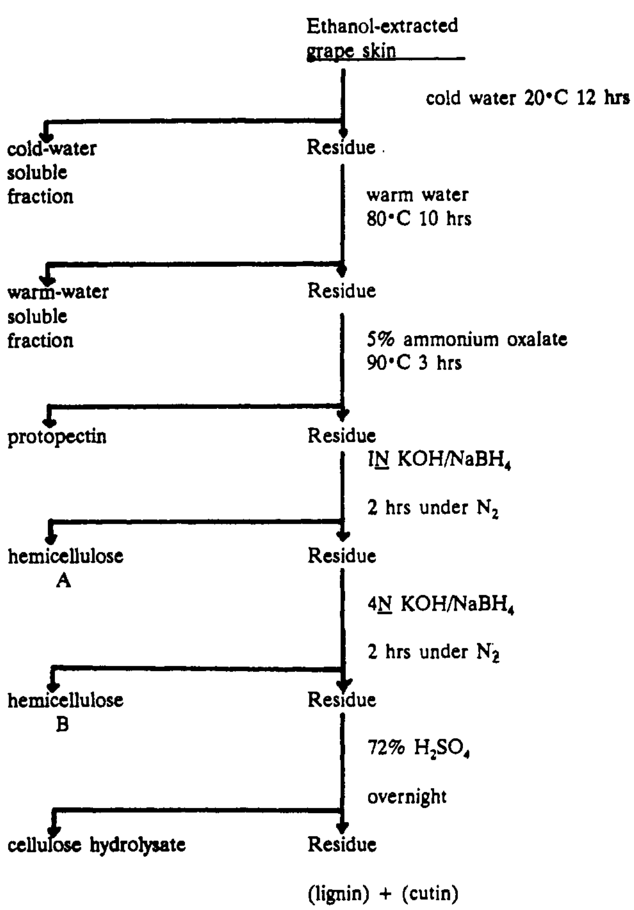

Figure 2. Grape skin polysaccharide fractionation.

fairly uniform characteristic irrespective of source. In addition, it is relatively easy to deseed, unlike the GWZ and TMD. This is important when large-scale pomace preparation is considered, since grape seeds have high levels of tannin (Singleton and Esau, 1969). Cell solubles content of the pomace samples studied were found to be intermediate between those of alfalfa and Sudan grass (Table II). The major components of the soluble portion of CBS pomace is shown in Table III, mainly organic acids (tartaric and acetic) and pectic substances. It is interesting to note that the pectic substances are not homopolysaccharides but contain pentose and hexose sugars either as side chains or as an integral part of the main polygalacturonide backbone (Albersheim, 1978). The digestibility of the cell solubles can be calculated to be about 70% from

$$DMD = (\%\ CW)(CWD) + (\%\ CS)(CSD)$$

where DMD = observed in vitro dry matter digestibility, % CW = cell wall content, CWD = observed in vitro cell wall digestibility, % CS = cell solubles content, and CSD = cells solubles digestibility.

This is lower than the 98% estimated in the white-tailed deer rumen (Robbins et al., 1975). It should be borne in mind that cell solubles of forages usually contain sugars, soluble carbohydrates, starch, pectin, and proteins. The cell solubles of CBS pomace may be less digestible than expected because of covalent interaction of the pectins with lignin present in high amounts in the grape cell wall (Wardrop and Bland, 1958). The organic acids present did not alter the pH of the rumen fluid/synthetic saliva mixture used in the digestibility determinations, and it can be assumed that they would be noninhibitory to rumen microbes. CBS pomace contains about 2% total phenols, but this has no adverse effect on its digestibility (Famuyiwa and Ough, 1982).

Table I. In Vitro Dry Matter Digestibilities of Pomace Varieties and Standard Feed[a]

	animal		
pomace	cow	sheep	goat
Cabernet Sauvignon	38.6 ± 0.4	37.0 ± 0.2	35.1 ± 0.2
Gewurtztraminer	35.9 ± 0.1	34.4 ± 0.2	31.4 ± 0.2
Tinta Madeira	25.8 ± 0.5	26.9 ± 0.3	25.9 ± 0.1
alfalfa/grain	68.6 ± 0.5	69.6 ± 0.3	66.2 ± 0.1
Sudan grass	62.6 ± 0.3	63.7 ± 0.3	78.0 ± 0.5

[a] Values expressed with the corresponding standard error of the mean (sem). sem = standard deviation/square root of sample size.

Table II. Fiber Characteristics of Grape Pomace and Control Feeds (Percent of Dry Matter)

material	cell solubles	celluose and hemicellulose	lignin and cutin	cell wall digestibility
Tinta Madeira	43.2	19.9	36.9	
Gewurztraminer	43.2	16.4	40.4	
Cabernet Sauvignon	49.9	20.7	29.4	4.1
alfalfa/grain	58.8	33.6	8.0	33.6
Sudan grass hay	33.2	60.0	5.0	41.8

Table III. Components of Water-Soluble Carbohydrates of Cabernet Sauvignon Pomace (Expressed as a Percentage of the Fraction)

	uronide content	organic acid	content	neutral sugar	content
cold water soluble fraction		tartaric acid	49.2	rhamnose	0.2
		acetic acid	31.4	arabinose	1.1
				xylose	0.5
				mannose	0.4
				galactose	0.8
	15.8		80.6		4.0
warm water soluble fraction		tartaric acid	9.5	rhamnose	2.9
		acetic acid	20.0	arabinose	12.5
				xylsoe	1.4
				mannose	4.9
				galactose	5.8
				glucose	4.4
	38.5		29.5		31.9

The major factor responsible for the observed low IVDMD of pomace appears to lie in the cell wall fraction. This constitutes 50% of CBS pomace dry matter, 41% of alfalfa, and 67% of sudan grass hay. However, while 60% of CBS pomace cell wall is lignin + cutin, only 16 and 7% of these recalcitrant polymers are present in the cell wall fraction of the standard feeds. Furthermore, IVCWD of the pomace is only 4%, compared with 33–42% for the standard feeds. Thus, about 50% of CBS dry matter is intrinsically indigestible, compared to 13% in alfalfa and 28% in Sudan grass hay. In addition, lignin is known to be covalently associated with cellulose and hemicellulose, thereby rendering a proportion of these fermentable substrates unavailable (Van Soest and Robertson, 1980). Further research in pretreatment and hydrolysis of pomace would be a key of effective utilization of pomace in feeds.

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Registry No. Cellulose, 9004-34-6; hemicellulose, 9034-32-6; lignin, 9005-53-2; tartaric acid, 87-69-4; acetic acid, 64-19-7; protopectin, 9012-27-5.