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Grape pomace

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Nutritional attributes

Grape pomace is a highly variable product. Not only does it contain variable proportions of pulp, stems, seeds and skins, but grape cultivars, fruit maturity, and the production process (winery, distillery, juice) all have effects on its composition. However, in spite of this variability, grape pomace is a feed of moderate to low nutritional value. Its protein content is about 14% of DM (11-16%) and its fibre content is generally high (ADF of 55% DM ranging from 43 to 66%) with exceptional levels of lignin (33% of DM, varying from 19 to 46%). Pomace containing only skins and pulp has a lower lignin content (17-26% of DM), though still much higher than that of most feeds (Bekhit et al., 2016). Grape pomace contains 4-8% of DM as lipids, due to the presence of its oil-rich seeds. Other components are also variable and depend, for instance, on cultivars and processes: pomace from red wine production contains residual yeast biomass and ethanol in addition to fermented grape material, whereas pomace from white wine production contains higher levels of water-soluble carbohydrates and less ethanol (Zheng Yi et al., 2012). Sugar content can vary from 4-9% (red wine pomace) to 28-31% of DM (white wine pomace) (Baumgärtel et al., 2007; Winkler et al., 2015).

Potential constraints

Tannins

Grape berries and their by-products, particularly the seeds and the skins, contain important though variable amounts of phenolic compounds, particularly flavonoids, which include anthocyanins, flavonols, and flavan-3-ols (catechin, epicatechin) (Chedea et al., 2016). Condensed tannins (proanthocyanidins) are polymers of flavan-3-ols of different molecular weights (Ye ZhiJing et al., 2016). Grape pomace can contain as much as 20% of DM as condensed tannins (Molina-Alcaide et al., 2008). These compounds form complexes with proteins in the feed and with digestive enzymes leading to disruption of the digestion process and to loss of nutrients. They also interfere with mineral absorption, causing damage to the mucosal lining of the gastrointestinal tract (Bekhit et al., 2016). Vinification methods influence the tannin content of grape pomace: particularly, higher fermentation temperatures and extended maceration times increase the release of phenolic compounds in the wine, and reduce their amount in the by-products (Ye ZhiJing et al., 2016). The high tannin content of grape pomaces is, together with fibre, one of the main reasons for their low digestibility and low nutritive value.

Flavonoids are recognized as antioxidants, with positive effects on the prevention of oxidative damage in tissues by the reduction of lipidic oxidation and/or blocking the production of free radicals (Letaief, 2016). For that reason, the inclusion of small amounts of grape pomace in the diets of ruminants, poultry, and pigs, is being investigated for its potential beneficial effects, both on animal health and on the quality of animal products. The effect of grape pomace tannins on the reduction of methane emissions by ruminants is also being studied (Moate et al., 2014).

Copper toxicity

There have been reports from Brazil of lethal intoxication of sheep fed grape pomace derived from grapevine treated with copper-based fungicides (Reis et al., 2015).

Pesticide residues

The grapevine is treated with a variety of pesticides. In Australia, an assessment of animal products derived from livestock fed grape pomace treated with registered pesticides found that the risk of residues was low with the majority of chemicals (MacLachlan, 2010).

Spoilage

Fresh grape pomace normally spoils readily. Depending on the conditions and on the nature of the product, it can remain edible for up to a week (Février et al., 2009), but it can also become inedible in less than 24 hours (Hentges et al., 1982).

Ruminants

Grape pomace has long been used to feed ruminants, though its use varies widely depending on the region. In the 2000s, its seasonal use was still reported in major wine growing regions such as France, Spain, Greece and the South of Australia, but it was little used in Germany (Baumgärtel et al., 2007). Grape pomace is generally seen as having low to moderate nutritional value, depending on the amount of stems, seeds and tannins in the product. Its feeding value has been found to be comparable to that of a hay or straw (Demarquilly et al., 1976; Hentges et al., 1982; Magnier, 1991; Winkler et al., 2015). Because of its low feeding value, grape pomace is more valuable for ruminants at maintenance or for low-producing animals, and should always be fed with supplementary protein and energy. A 10-day transition is recommended when introducing it into the diet. Grape pomace is more suitable for sheep and goats than for cattle, though it can be given to beef cows and heifers (Magnier, 1991).

Since 2000, research has focused on the potential benefits of grape pomace phenols on animal health, product quality and environmental issues, such as N excretion and methane emissions.

Palatability and intake

Grape pomace has long been described as being palatable to ruminants. Sheep were observed to select the seeds and the skins and to discard the stems when fed whole pomace (Cornevin, 1892). Sheep consumed 90 to 130 g DM/kg $W^{0.75}$ (1.5-2,5 kg/d for a 60 kg sheep) of fresh or ensiled grape marc. Intake was lower for dried pomace and exhausted pomace. Grape pomace without seeds and stems was also palatable but intake was slightly lower (50 to 122 g DM/kg $W^{0.75}$) (Magnier, 1991). Fresh grape pomace fed to grazing yearling heifers and beef cows was found very palatable. Beef cows could consume up to 13.6 kg of pomace in 2 hours (Hentges et al., 1982).

Digestibility and degradability

In vitro and *in vivo* digestibility of grape pomace is generally low to very low, with few exceptions, in the 25-35% range (Magnier, 1991). *In vitro* DM digestibility of pomace from 3 grape cultivars in cattle, sheep and goat ranged from 26 to 36%, the lowest values corresponding to the highest content in phenolics (Oluyemi et al., 1982). In a comparison of 2 types of winery grape pomace, *in vivo* OM digestibility ranged from low (red wine, 32%) to medium (white wine, 56%). The first pomace had 31% NDF and 4% sugars while the other had 51% NDF and 27% sugars (Baumgärtel et al., 2007). However, another trial found red wine pomace to have a better OM digestibility than white wine pomace (39 *vs.* 32%) (Winkler et al., 2015). A comparison of red and white grape pomaces gave higher *in vivo* OM digestibility values for white grape pomace (39 *vs.* 32%) (Zalikarenab et al., 2007). A trial in China with fistulated sheep concluded that 2.25 g/kg DM condensed tannins from grape pomace improved the apparent digestibility and retention of feed protein (Zhao Dong et al., 2014).

Rumen degradability was also found to be low. Some authors reported values in the 25-40% range for DM effective degradability (Molina-Alcaide et al., 2008; Abarghuei et al., 2015), while other authors reported values lower than 20% (Sarcicek et al., 2002). There is a wide range of N degradability, from very low values (less than 20%) reported for juice pomace (Abarghuei et al., 2015; Sarcicek et al., 2002), to values in the 40-50% range (Molina-Alcaide et al., 2008).

Dairy cows

Grape pomace is generally not recommended for dairy cows as it tends to depress milk yield (Magnier, 1991). Early trials showed that grape pomace without stems could be fed to dairy cows in amounts up to 6.5 kg/d and was a good feed when supplemented with concentrates and legume hay, though at this level of inclusion the milk yield tended to drop and the butterfat content increased. Larger amounts caused inflammation of the mucosa in the digestive system (Göhl, 1982). In Greece, dairy cows were fed a diet containing 20% ensiled wet grape marc without affecting DM intake, milk yield, milk composition, and body condition (Belibasakis et al., 1996). In Australia, the feeding of dried grape marc (5 kg DM/d) instead of alfalfa hay to dairy cows in late lactation had no effect on milk yield or concentrations of protein and lactose in the milk, but milk fat concentration and, consequently, yield of milk fat was reduced. With the same amount of ensiled grape marc there was no effect on the concentrations of milk fat, milk protein, and milk lactose, but milk yield and yields of milk fat, milk protein, and milk lactose were all reduced. The feeding of both dried and ensiled grape marc resulted in milk fat with enhanced concentrations of MUFA, PUFA, and cis-9, trans-11 linoleic acid (Moate et al., 2014).

Since 2000, studies have investigated the potential benefits of the flavonoids and antioxidants contained in grape pomace. In Denmark, dairy cows fed a high protein diet supplemented with 4.5 g/d of grape pomace did not show any significant improvement in yields of milk and protein (Nielsen et al., 2004). In Romania, dried grape pomace included at 3 to 5 kg/d had no effect on milk yield and composition (Nistor et al., 2014). In Germany, supplementation of dairy cows with 1% grape seed and marc meal extract (containing 5.2% polyphenols) from week 3 prepartum to week 9 postpartum increased milk production. There was no significant effects on inflammation and the occurrence of endoplasmic reticulum stress in the liver of dairy cows during early lactation (Gessner et al., 2015).

Other effects of grape marc flavonoids on dairy metabolism have been researched. In New Zealand, cows receiving 3 kg DM/d of grape pomace excreted 22% more N in faeces compared with the control group, had a lower plasma urea nitrogen concentration and unchanged urine urea concentration. This altered partitioning of N toward the faeces instead of absorption could be beneficial when feeding diets high in rumen-degradable protein (Greenwood et al., 2012). In Australia, dairy cows fed 5 kg DM/d of dried or ensiled grape pomace showed a 20% reduction in CH_4 emissions without a concomitant reduction in DM intake. These reductions in CH_4 emissions were associated with changes in the rumen bacterial and archaeal communities (Moate et al., 2014).

Beef cattle

Most trials involving growing beef cattle show that including grape pomace above 10% of the diet is detrimental to performance. In Cyprus, the inclusion of dried grape marc at 15% and 30% of calf fattening diets reduced killing-out percentage but increased feed intake, thus reducing efficiency of feed utilization. At 30% inclusion live-weight gain was reduced (Hadjipanayiotou et al., 1976). Similar results were obtained in a trial in California, USA, where dried grape pomace mixed at 20% to replace barley in finishing steer diets had no effect on gain or carcass composition but increased intake by 15%, which was detrimental to feed efficiency (Hentges et al., 1982). In Chile, steers fed diets containing up to 15% grape marc showed decreasing live-weight gains 45 days into the trial. Body weight, carcass yield, dorsal fat and loin eye area were also negatively affected (Manterola et al., 1997). Likewise, negative results on daily gain and feed efficiency were obtained with young cattle fed 15 to 22.5% grape marc in the diet (Stojanovic et al., 1989). Not all trials were negative: in Romania, replacing barley by dried grape pomace (20% of the diet) for fattening steers did not affect performance (Voicu et al., 2014). Grape pomace was fed at up to 35% of the diet of beef cows with low requirements (Magnier, 1991).

Sheep

Growing sheep

In Cyprus, lambs fed diets containing 30% grape marc as a substitute for barley made similar live-weight gains as the lambs fed the control diet, but consumed more feed, thus feed efficiency was lower. It was recommended to use diets containing 10-15% grape marc with a source of nitrogen (Economides et al., 1980). In Greece, sheep fed diets containing up to 40% grape marc for 10 days showed decreased protein digestibility when it was included at 20% and above (Fegeros et al., 1987). In Iran, feeding male lambs on diets containing up to 10% dried grape pomace (from juice production) improved growth as well as the triglyceride level. 15% and above in the diet was detrimental to growth and feed efficiency (Bahrami et al., 2010a; Bahrami et al., 2010b). In Spain, feeding lambs with a small amount (5%) of dried red grape marc did not affect intake, daily gain, carcass yield and carcass characteristics (Guerra-Rivas et al., 2013b). In Romania, feeding above 125 g/d of dried grape pomace was detrimental to growth (Nistor et al., 2014). A study in China was more positive, in that lamb diets containing 8-16% of grape pomace improved feed conversion efficiency, daily weight gain, carcass characteristics and nutrient utilization (Lu ZhenZhen et al., 2015).

Ewes

In Greece, grape marc included at 19% in the diets of dairy ewes increased PUFA concentration in the milk as well as the concentration of cis-9,trans-11 CLA and vaccenic acid (C18:1 trans-11) (Tsiplakou et al., 2008). However, a study in Spain with ewes fed 5 or 10% red grape wine pomace (combined with 2.7% linseed oil) concluded that grape pomace did not affect the percentages of total saturated, monounsaturated, and polyunsaturated fatty acids (Manso et al., 2016).

In Spain, the effect of grape pomace in the diet of lactating ewes on their lambs was investigated. Diets containing 5 or 10% of red grape wine pomace resulted in lambs having higher levels of vaccenic acid, rumenic acid (C18:2 cis-9, trans-11) and a higher n3:n6 ratio in the intramuscular fat, though the PUFA and saturated fatty acids were not affected. The lipid oxidation during storage was lower for the meat of lambs whose dams were fed grape pomace (Guerra-Rivas et al., 2015a; Guerra-Rivas et al., 2015b).

Goats

In Greece, grape marc included at 19% in the diets of dairy goats had little or no effect on the fatty acid profile of milk (Tsiplakou et al., 2008).

Pigs

Grape pomace has a low nutritive value for pigs due to its high fibre and tannin contents, so there is little information regarding feeding it to pigs. In Australia, dried winery pomace included in pig diets decreased feed efficiency when fed at 15% and above, and decreased weight gain when fed at 20% and above (Farrell et al., 1983). In France, destemmed grape pomace was included in pig diets at up to 20% (Février et al., 2009).

Since the year 2000, grape pomace added in limited amounts (5% or less) has been investigated as a source of beneficial proanthocyanidins, flavonoids and fatty acids. Feeding piglets a diet containing 3.5% (DM basis) red grape pomace increased the number of colonic bacteria (Streptococci, Enterococci, Lactobacilli), and positively influenced the mRNA expression pattern of immunological marker genes in white blood cells (Sehm et al., 2011). In Korea, feeding finishing pigs with a diet containing 3% dried grape pomace fermented with *Saccharomyces boulardii* had a positive effect on average daily gain, DM and N digestibility, altered the fatty acid profile of the subcutaneous fat (reduced saturated fatty acids and increased PUFA) and meat quality attributes (marbling score, redness and yellowness values, anti-oxidative ability) (Yan et al., 2011). In Romania, the addition of 5% dried grape pomace in the diet of growing pigs increased the concentration of n-3 fatty acids (particularly α-linolenic acid) in the *longissimus dorsi* muscle (Habeanu et al., 2015).

Poultry

Grape pomace has a low nutritive value for poultry due to its high fibre and tannin contents, and there is little information about its use for feeding it to poultry. Most of the work done since the year 2000 concerns the use of grape pomace for its potential benefits on health and product quality.

Broilers

In Australia, dried winery pomace included in broiler diets decreased feed efficiency when fed at 12% and above, and decreased weight gain when fed at 18% and above (Farrell et al., 1983). Later studies have tested much smaller amounts of grape pomace, usually between 1 to 6% of the diet. Several studies in Spain have looked at the effects of grape pomace or grape pomace concentrate on broiler meat quality, gut flora and morphology (Chamorro et al., 2015). Grape pomace added at 0.5 to 3% of the diet for broilers reduced the lipid oxidation of meat during refrigerated storage and increased liver α-tocopherol concentration (Goñi et al., 2007). A grape pomace concentrate (containing 15% condensed tannins) included at up to 6% in broiler diets did not impair chicken growth, digestive organ size, and protein digestibility. There was increased antioxidant activity in diet, excreta, ileal content, and breast muscle. It was as effective in antioxidant potential as vitamin E. In a later experiment, a diet including 6% of the similar grape pomace concentrate increased the biodiversity of intestinal bacteria and modified gut morphology in a way potentially favourable to nutrient absorption (Brenes et al., 2008; Viveros et al., 2011). In Iran, red grape pomace (from juice production) included in broiler diets decreased broiler performance linearly when added at more than 2%, but it also increased blood glucose level and plasma antioxidant content (Khodayari et al., 2014). In Romania, grape pomace included at 2% in broiler diets had a slight positive effect on performance (Pop et al., 2015).

Laying hens

In the USA, feeding grape pomace has been tested successfully to induce molting before the second laying phase (McKeen, 1984). In Turkey, the addition of up to 6% grape pomace in the diet of laying hens did not significantly affect performance, egg quality, and serum total cholesterol, total protein and triglyceride levels. It also reduced egg yolk malondialdehyde (MDA), which may improve egg shelf life (Kara et al., 2016).

Horses and donkeys

Grape marc has been used for horses at up to 10% of the diet (Göhl, 1982).

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