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Food Applications of Grape Pomace: Nutritional, Antioxidant and Functional Insights

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INTRODUCTION & AIM

The wine industry is one of the largest and most influential sectors within the global agri-food system, with an annual production that generates millions of tonnes of by-products, primarily grape pomace (OIV, 2023). Grape pomace, which consists mainly of skins, seeds, and residual pulp, represents approximately 20–30% of the total grape weight used in winemaking. Despite being traditionally regarded as waste and often discarded or used as low-value animal feed and fertilizer, this by-product is increasingly recognized as a valuable source of bioactive compounds with significant nutritional and therapeutic potential (Piccoli et al., 2022; Pereira et al., 2020).

Recent studies have highlighted that grape pomace is exceptionally rich in polyphenols, flavonoids, tannins, anthocyanins, dietary fiber, and unsaturated fatty acids, which contribute to its high antioxidant, anti-inflammatory, antimicrobial, and cardioprotective activities (Pereira et al., 2024). The reutilization of this by-product not only reduces the environmental footprint of winemaking but also enhances the economic sustainability of the wine sector by enabling the development of high-value-added products.

Therefore, this study aims to characterize the bioactive and nutritional profile of grape pomace flours obtained from the Touriga Nacional and Arinto varieties, evaluating their potential for sustainable valorization.

METHODOLOGY

Table 1: Grape pomace samples from two varieties (red and white grapes) and three wineries (different locations and grape processing).

Samples ID	Variety	Winery
TC	Touriga Nacional (red)	Carmin
TCP		Cerrado da Porta
TM		Mingorra
AC	Arinto (white)	Carmin
ACP		Cerrado da Porta
AM		Mingorra

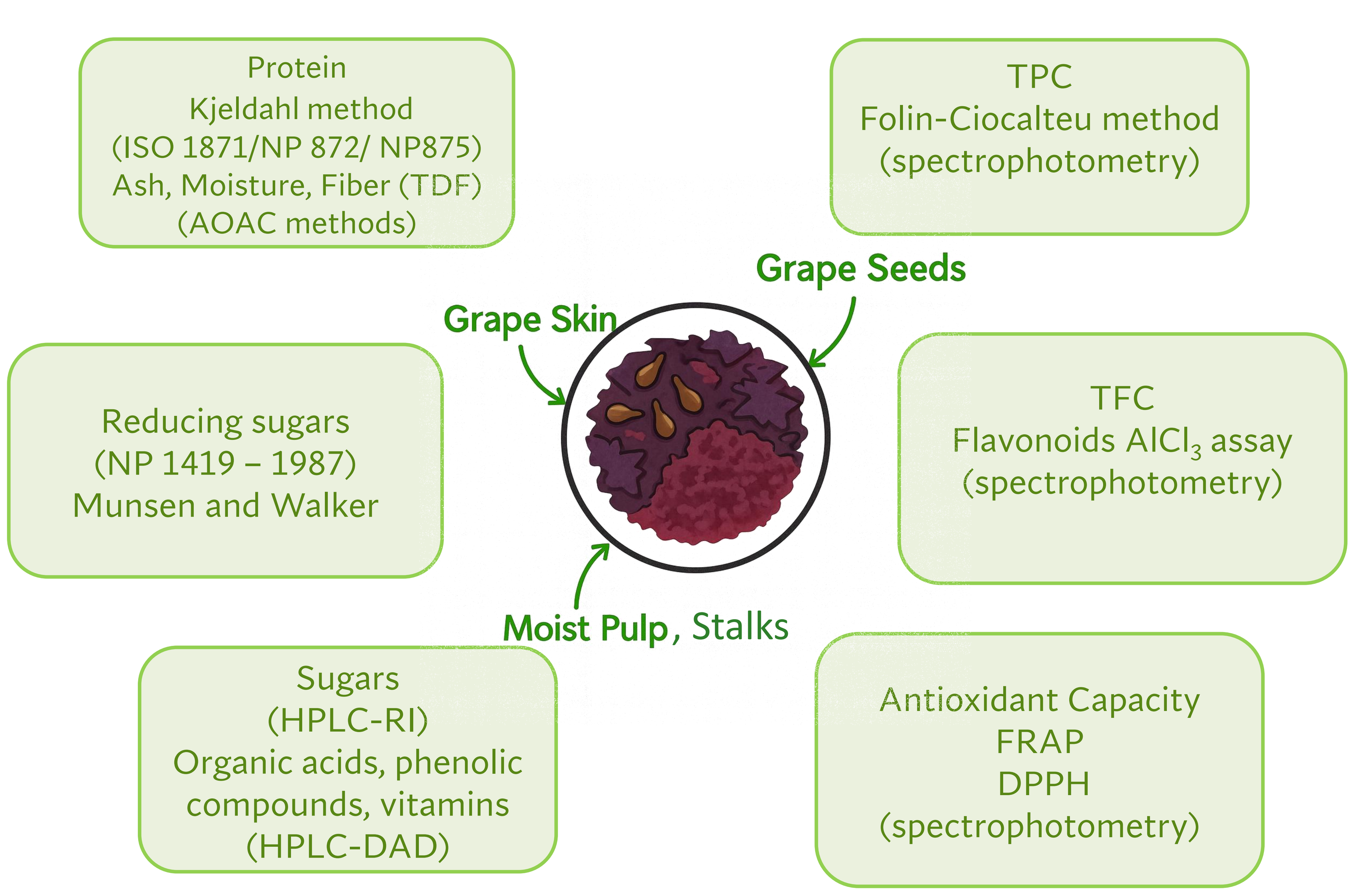

Figure 1. Analytical workflow for grape pomace composition and antioxidant profiling.

CONCLUSIONS

Grape pomace is not waste but a high-value reservoir of bioactives—polyphenols, dietary fibre and B-vitamins—with nutritional and therapeutic potential.

Its incorporation into foods, cosmetics and pharmaceutical prototypes adds antioxidant/anti-inflammatory functionality and supports evidence-based product development.

Valorising grape pomace within a circular bioeconomy reduces waste and environmental impact while generating safe, traceable, value-added products.

FUTURE WORK

- **Food**: prototype fortified foods; ensure safety/quality; extend shelf-life; assess bioavailability; LCA & scale-up.
- **Cosmetics**: standardize extracts; prove efficacy; stabilize formulations; safety/compliance.
- **Pharma**: identify actives; advanced delivery; preclinical/clinical evidence; regulatory/IP.
- **Cross-cutting**: traceability; method standards; industry–academia partnerships.

RESULTS & DISCUSSION

Tabela 2. Phenolic profile of grape pomace samples (mg/100 g).

mg/100 g	AC	ACP	AM	TC	TCP	TM
Gallic acid	9,03 ± 0,66[bc]	17,73 ± 0,99[a]	16,99 ± 0,41[a]	8,19 ± 1,54 [c]	9,35 ± 1,39[bc]	11,68 ± 0,01[bc]
Protocatechuic	204,28± 11,42[b]	257,03 ±22,34[a]	266,33 ±6,00[a]	78,90 ± 2,13[c]	87,50 ± 75,73[c]	193,07 ±10,99[b]
Procyanidin B1	62,48 ± 2,29[ab]	50,80 ± 3,73[b]	76,54 ± 8,75[a]	20,70 ± 3,60[c]	24,23 ±5,43[c]	32,40 ± 1,56[c]
Catechin	64,63 ± 4,93[b]	104,61 ± 8,22[a]	79,06± 12,45[ab]	23,36 ± 2,71[c]	19,21 ± 9,82[c]	26,34 ± 7,92[c]
Chlorogenic	3,29 ± 0,29[b]	3,18 ± 0,08[b]	3,03 ± 0,02[b]	4,70 ± 0,10[b]	4,68 ± 3,80[b]	8,89 ± 1,89[a]
Hydroxybenzoic	8,85 ± 0,39[b]	30,35 ± 8,37[a]	20,96 ± 3,03[ab]	10,58 ± 2,13[b]	10,38 ± 2,35[b]	13,86 ± 0,82[b]
Caffeic	7,63 ± 0,03[b]	8,02 ± 0,19[b]	7,82 ± 0,43[b]	8,28 ± 0,08[b]	8,30 ± 0,14[b]	9,74 ± 0,18[a]
Vanillic	17,09 ± 1,09[cd]	32,97 ± 2,86[a]	24,41 ± 1,02[b]	14,23 ± 1,44[d]	14,12 ± 4,17[d]	21,27 ± 0,12[bc]
Syringic	14,79 ± 0,71[a]	4,65 ± 0,15[b]	4,89 ± 0,43[b]	5,62 ± 0,66[b]	5,59 ± 0,32[b]	5,44 ± 0,29[b]
Epicatechin	7,29 ± 1,91[a]	10,05 ± 2,04[a]	7,15 ± 2,29[a]	13,31 ± 5,07[a]	15,04 ± 3,34[a]	18,96 ± 3,91[a]
Vanillin	0,51 ± 0,27[a]	0,84 ± 0,04[a]	0,67 ± 0,01[a]	0,46 ± 0,08[a]	0,41 ± 0,01[a]	0,35 ± 0,07[a]
Coumaric	7,44 ± 0,03[a]	7,54 ± 0,13[a]	7,60 ± 0,27[a]	7,60 ± 0,16[a]	7,61 ± 0,30[a]	7,84 ± 0,23[a]
Rutin	22,51 ± 1,48[a]	22,15 ± 0,66[a]	22,12 ± 1,83[a]	10,73 ± 2,99[b]	10,10 ± 3,16[b]	12,48 ± 0,72[b]
Elagic	73,47 ± 0,41[a]	73,07 ± 0,81[a]	73,10 ± 0,99[a]	73,68 ± 1,63[a]	73,66 ± 1,11[a]	74,46 ± 0,01[a]
Ferulic	4,45 ± 0,05[a]	4,41 ± 0,05[a]	5,08 ± 0,59[a]	4,39 ± 0,07[a]	4,52 ± 0,30[a]	4,73 ± 0,15[a]
Naringin	5,45 ± 0,40[a]	5,28 ± 0,62[a]	5,05 ± 0,05[a]	5,08 ± 0,14[a]	5,50 ± 0,09[a]	5,10 ± 0,04[a]
Apigenin 7gluc	60,79 ± 0,18[a]	60,57 ± 0,84[a]	60,78 ± 1,19[a]	61,14 ± 1,44[a]	61,06 ± 1,00[a]	61,80 ± 0,16[a]
Miricetin	60,70 ± 0,18[a]	60,56 ± 0,48[a]	60,72 ± 0,85[a]	61,07 ± 1,35[a]	61,01 ± 0,99[a]	61,73 ± 0,19[a]
Resveratrol	5,21 ± 0,07[a]	5,16 ± 0,02[a]	4,90 ± 0,15[a]	4,94 ± 0,13[a]	4,93 ± 0,20[a]	5,12 ± 0,06[a]
Quercetin	3,70 ± 0,70[a]	3,12 ± 0,01[a]	3,37 ± 0,14[a]	3,14 ± 0,04[a]	3,19 ± 0,03[a]	3,17 ± 0,01[a]
Kaempferol	1,85 ± 0,11	1,85 ± 0,04[a]	1,79 ± 0,19[a]	1,67 ± 0,05[a]	1,73 ± 0,03[a]	1,69 ± 0,01[a]
Total Phenolic HPLC	645,8 ± 24,1[bc]	764,3 ± 50,9[a]	752,4 ± 26,9[b]	421,8 ± 6,9[d]	436,7 ± 109,9[d]	580,2 ± 28,9[c]

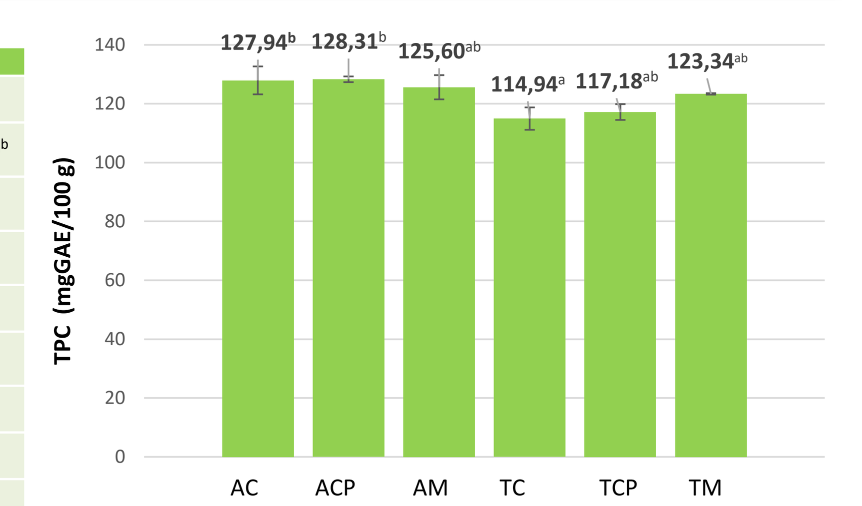

Figure 2. Total phenolic content (TPC) of grape pomace samples (mg GAE/100 g).

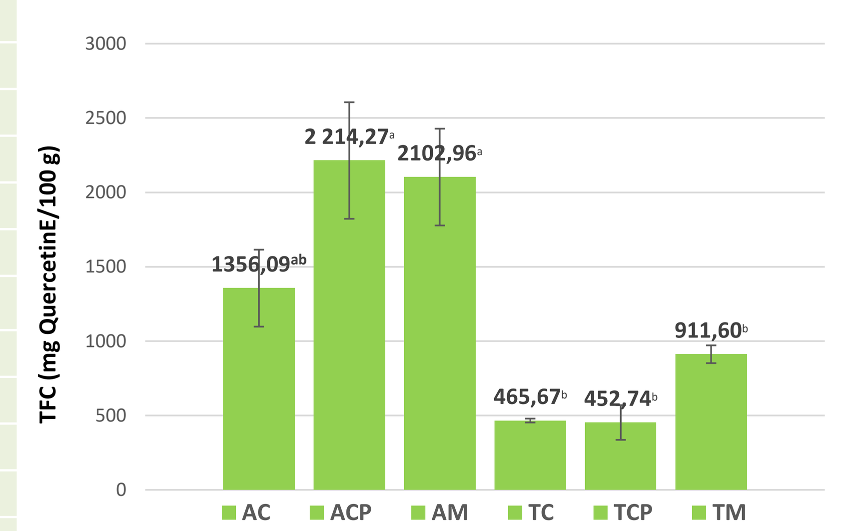

Figure 3. Total flavonoid content (TFC) of grape pomace samples (mg quercetin equivalents/100 g).

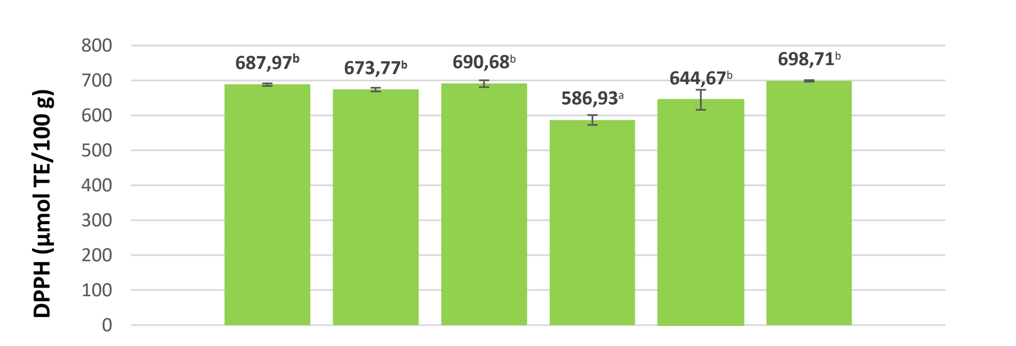

Figure 4. DPPH radical-scavenging capacity of grape pomace samples (µmol Trolox equivalents/100 g).

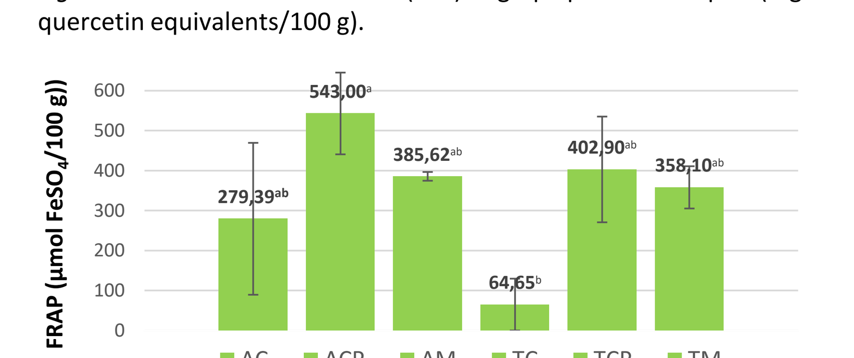

Figure 5. FRAP of grape pomace samples (µmol $FeSO_4$/100 g).

Table 3. Macronutrients, free sugars, organic acids, and B-vitamins in grape pomace samples.

Samples	Sucrose (%)	Glucose (%)	Fructose (%)	Reducing Sugars (%)	Oxalic (mg/100 g)	Citric (mg/100 g)	Succinic (mg/100 g)	Formic (mg/100 g)	Acetic (mg/100 g)	Malic (mg/100 g)
AC	0,42 ± 0,0002[a]	4,83 ± 0,14[b]	4,54 ± 0,13[b]	16,43 ± 0,79[a]	68,40 ± 24,26[bc]	223,24 ± 37,19[b]	493,39 ± 102,33[b]	325,35 ± 157,35[bc]	775,35 ± 135,04[b]	150,98 ± 26,7[b]
ACP	0,46 ± 0,02[a]	4,30 ± 0,44[b]	4,47 ± 0,46[b]	10,83 ± 2,54[ab]	139,08 ± 13,12[a]	510,16 ± 104,52[b]	1098,89 ± 40,19[a]	1312,34 ± 10,59[a]	1233,24 ± 26,26[a]	248,42 ± 17,4[a]
AM	0,47 ± 0,22[a]	10,98 ± 0,39[a]	9,29 ± 0,30[a]	16,18 ± 4,29[a]	79,41 ±14,27[b]	249,68 ± 56,09[b]	930,66 ± 58,78[a]	1131,79 ± 67,73[a]	600,32 ± 7,79[bc]	135,62 ± 16,36[b]
TC	0,39 ± 0,009[a]	1,15 ± 0,02[c]	1,16 ± 0,01[c]	3,31 ± 0,07[bc]	22,57 ± 0,28[c]	94,08 ± 21,87[b]	567,97 ± 53,07[b]	191,72 ± 15,37[c]	258,82 ± 3,2[c]	77,83 ± 7,4[b]
TCP	0,31 ± 0,006[a]	0,42 ± 0,007[c]	0,25 ± 0,003[c]	2,41 ± 2,22[bc]	20,9 ± 1,31[c]	70,6 ± 8,75[b]	444,93 ± 18,47[b]	182,69 ± 70,24[c]	309,26 ± 211,76[c]	101,75 ± 36,93[b]
TM	0,39 ± 0,02[a]	0,67 ± 0,03[c]	0,48 ± 0,02[c]	1,48 ± 0,02[c]	34,12 ± 0,59[bc]	130,24 ± 3,20[a]	602,34 ± 71,93[b]	517,5 ± 64,33[b]	560,02 ± 3,97[bc]	106,30 ± 9,92[b]

Samples	Propionic (mg/100 g)	TDF (%)	Fat (%)	Protein (%)	Ash (%)	Moisture (%)	Thiamin B1 (mg/100 g)	Riboflavin B2 (mg/100 g)	Niacin B3 (mg/100 g)	Panthotenic B5 (mg/100 g)
AC	748,5 ± 134,58[a]	50,88± 1,33[ac]	7,24 ± 0,03[d]	8,41 ± 0,13[c]	8,50 ± 1,06[bc]	8,05 ± 0,15[b]	0,016 ± 0,0085[c]	0,015 ± 0,00071[c]	0,18 ± 0,016[bc]	0,097 ± 0,013[a]
ACP	1261,56 ± 540,52[a]	48,20± 2,83[c]	11,80 ± 0,29[a]	8,22 ± 0,32[c]	3,70 ±0,06[a]	8,08 ± 0,20[b]	0,044 ± 0,0021[ac]	0,017 ± 0,00[bc]	0,10 ± 0,0064[d]	0,065 ± 0,0014[ab]
AM	893,64 ± 3,28[a]	45,29± 3,11[c]	4,54 ± 0,23[b]	5,49 ± 0,19[b]	4,17 ± 0,55[a]	7,16 ± 0,10[ab]	0,02± 0,015[c]	0,015 ± 0,00071[c]	0,12 ±0,016[cd]	0,082 ± 0,015[ab]
TC	441,14 ± 28,19[a]	58,79± 0,04[ab]	9,06 ± 0,12[b]	9,17 ± 0,02[c]	7,90 ± 0,43[bc]	7,90 ± 1,19[b]	0,063 ± 0,0050[ab]	0,019 ± 0,00[b]	0,25 ± 0,011[a]	0,053 ± 0,00071[b]
TCP	456,59 ± 128,88[a]	64,97± 2,37[b]	7,70 ± 0,30[d]	5,65 ± 0,69[b]	7,02 ± 0,12[c]	6,10« ± 0,11[ab]	0,079 ± 0,0021[b]	0,024 ± 0,0014[a]	0,14 ± 0,0028[cd]	0,062 ± 0,0050[b]
TM	523,87 ± 4,43[a]	61,39± 0,33[b]	6,29 ± 0,15[c]	2,10 ± 0,05[a]	9,66 ± 0,44[b]	5,40 ± 0,012[a]	0,079 ± 0,0007[b]	0,016 ± 0,00[c]	0,22 ± 0,028[ab]	0,065 ± 0,0070[ab]

Hierarchical Cluster and Principal Component Analysis

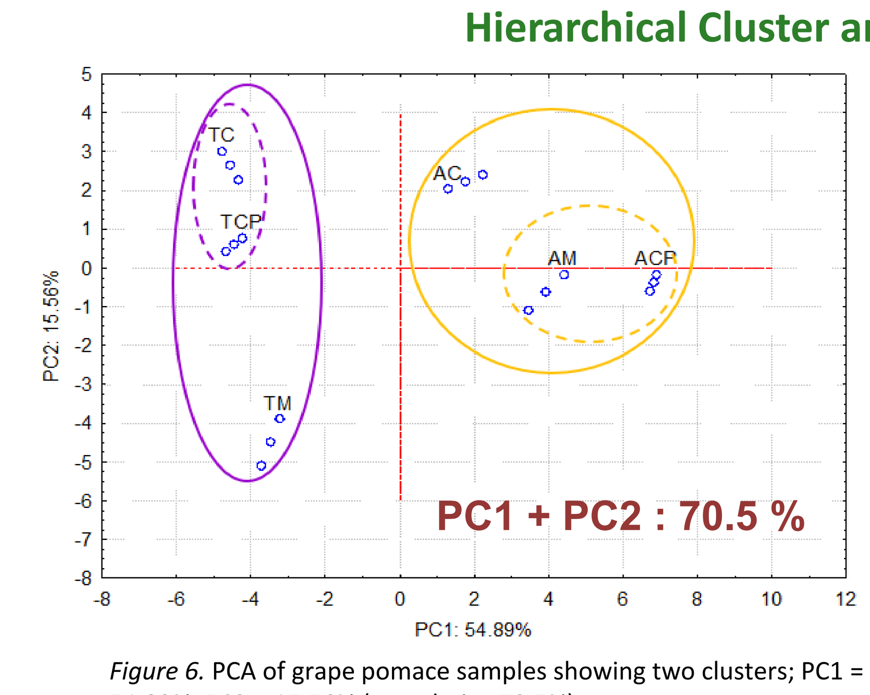

Figure 6. PCA of grape pomace samples showing two clusters; PC1 = 54.89%, PC2 = 15.56% (cumulative 70.5%).

- Variety separation at ED* 8.5 (T and A).
- For T, two wineries (C and CP) were separated from M at ED 4.75, and for A, two wineries (M and CP) were separated from C at ED 8. PC1 is strongly influenced by phenolic and flavonoid compounds, reducing sugar, organic acids (positively); ash, fibre, vitamin B1 and B3 (negatively).
- PC2 is strongly influenced by moisture and protein (positively), and hydroxycinnamic acids (negatively).

*ED = Euclidean distance

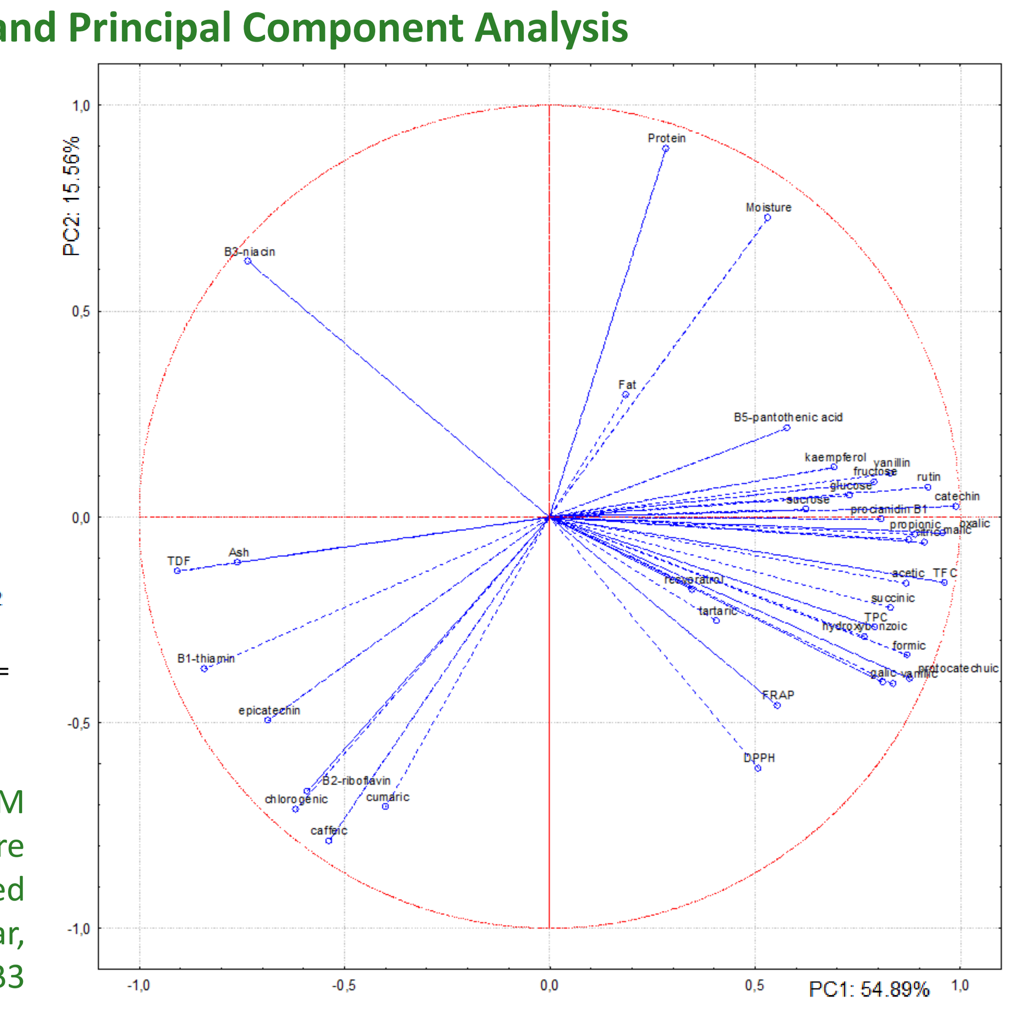

Figure 7. Variable projection on the PC1/PC2 plane; loadings driving sample separation..

- PC1 influenced the variety separation, and PC2 the winery.

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