Prediction of sheep milk chemical composition using pH, electrical conductivity and refractive index

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Milk quality traits

- Milk quality traits (fat, protein, lactose and total solids content)

- Directly linked to the processing performance of sheep milk

- Improvement of milk quality traits → Dairy industry's demand

- Milk quality traits are expensive and difficult to measure
- Need laboratories with trained staff
- Normally done by organized farmers' networks and cooperatives
- Logistics for the transferring of samples
- Considerable capital investment

The situation in Greece

- **Farmers in Greece**

- **Do not have easy access to these labs**

- **Do not consider breeding for milk quality because it is expensive and difficult to measure**

The idea…

- **Can we use other physical traits to select for milk quality?**
  - **Other trait might include pH, milk electrical conductivity, refractive index**

- **Utilize 1) low-cost, 2) readily-used and 3) suitable for on-farm use, analyzers**

Objective

To assess if pH, electrical conductivity and refractive index of sheep milk can predict its fat, protein, lactose and total solids content

Animals and measurements

- **308 Frizarta ewes from two semi-intensive flocks**

- **Composite milk samples in 50 ml capacity tubes**

- **Milk electrical conductivity (MEC) and pH were measured (pH/conductivity meter (EZDO 7200, GMM Technoworld®)**

- **Refractive index (RI) was measured with a portable Brix (0-25 °Bx) (RHW-25ATC-BE, Hong Han Technologies)**

- **Milk quality traits were measured using MilkoScan™, Foss**

Statistics

SPSS

Multiple stepwise regression analysis

predicted variable = intercept + pH + MEC + RI + e

the predicted variables were milk quality traits (fat, protein, lactose and total solids content)

e = random error

Assumptions testing passed

**Assumptions of normality, linearity and homoscedasticity:**

- **Plots of standardized residuals against standardized predicted values**

- **Probability-probability plots (p-p plots) of regression standardized residuals**

- **Variance inflation factor (VIF) was calculated for each predictor to ensure there was no violation of the assumption of multicollinearity**

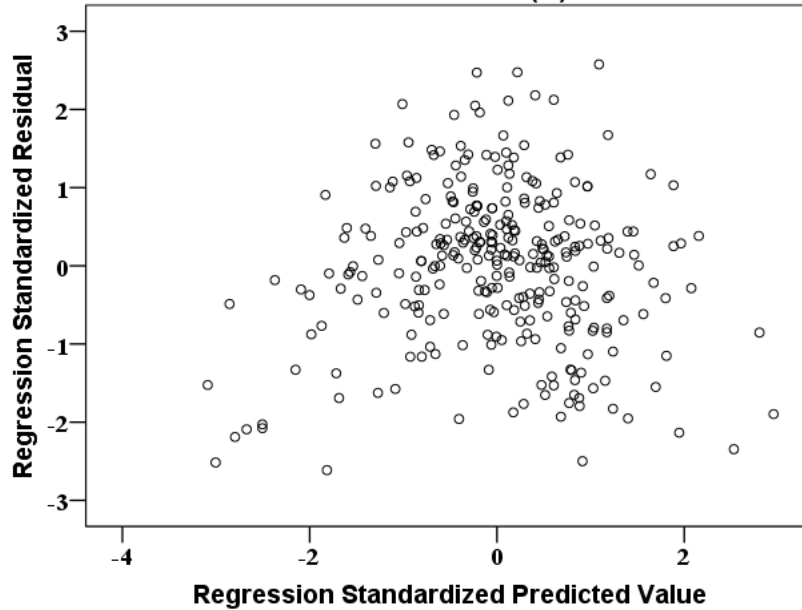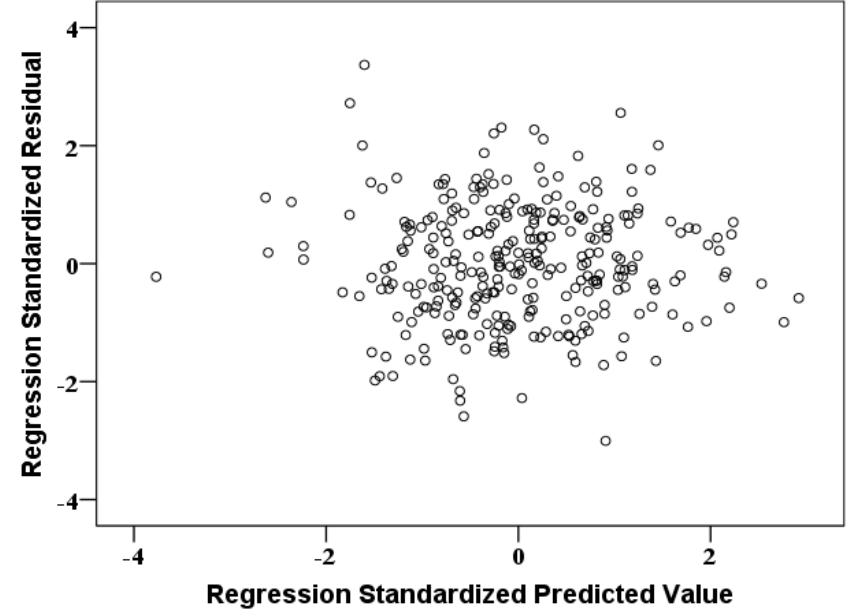# Plots of standardized residuals against standardized predicted values

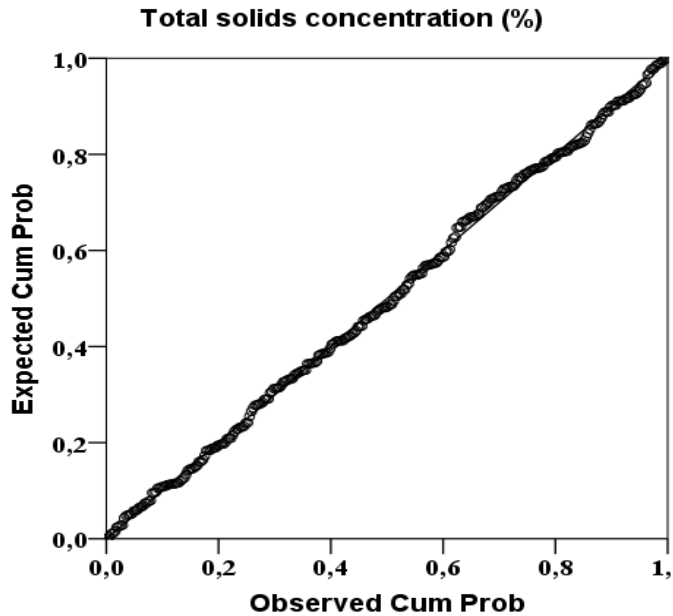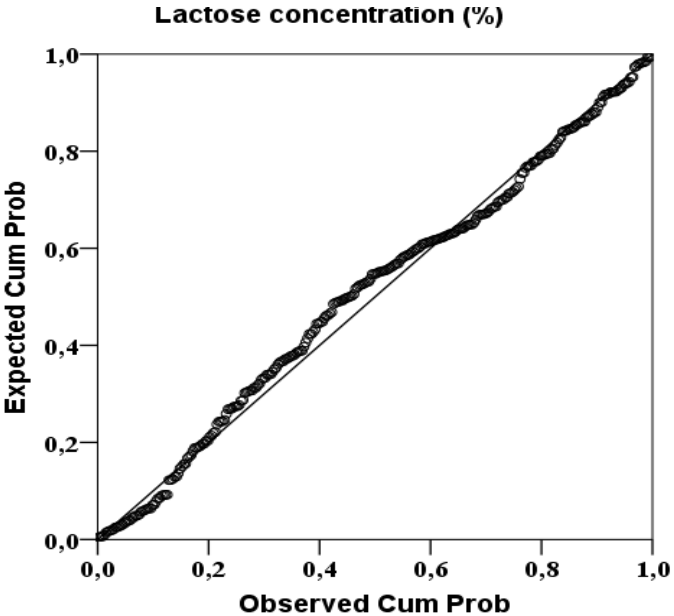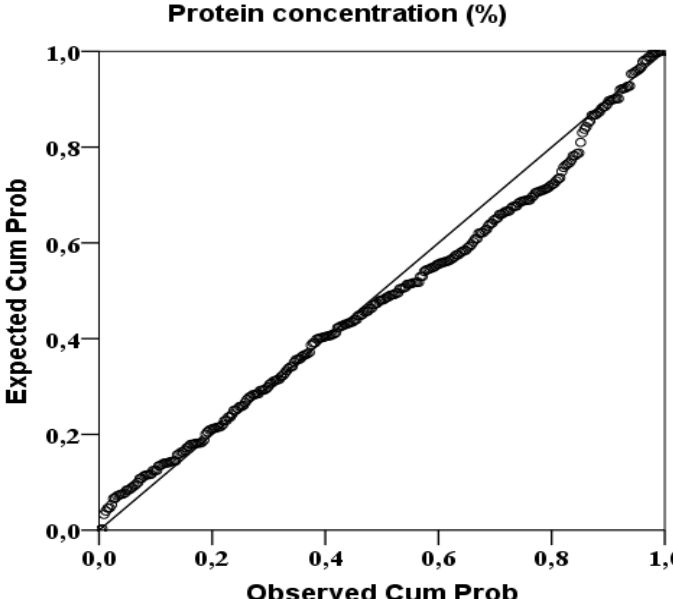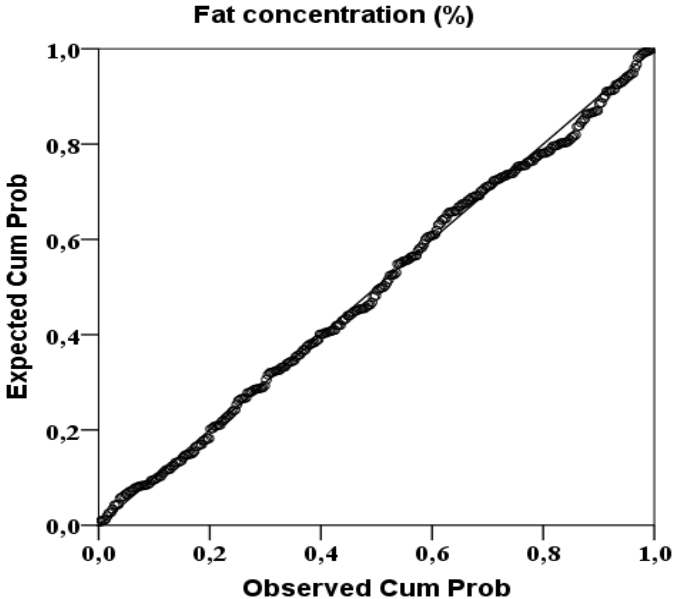Fat concentration (%)
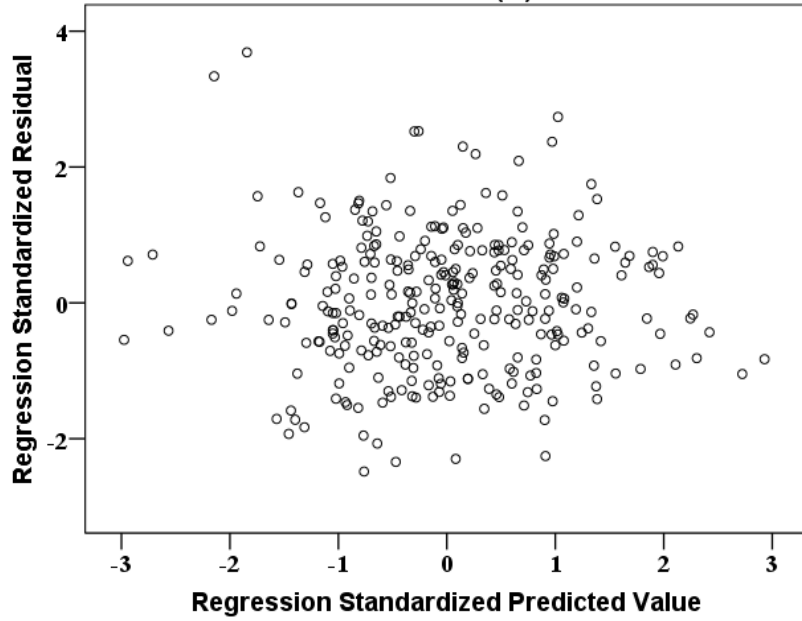
Protein concentration (%)
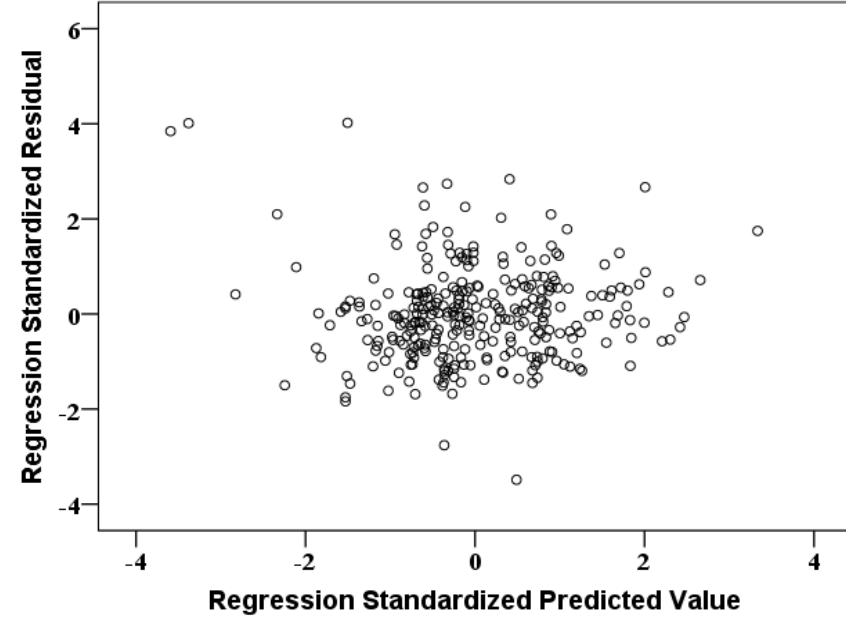
Lactose concentration (%)

Total solids concentration (%)

Probability-probability plots (p-p plots) of regression standardized residuals

Validation

Prediction models were validated using:

- **Bootstrapping - 1,000 bootstrap samples were repeatedly resampled, with replacement**

- **Split-half cross validation**

- **Regression coefficients, standard errors, 95% confidence intervals and p-values for the overall model and for the predictors were calculated**

- **Statistical significance was set at P≤0.05**

Descriptives

Physical properties of sheep milk and milk quality traits

Variable	Mean	Std. Dev.
pH	6.7	0.14
Conductivity (ms/cm)	4.0	0.36
Refractive index (°Bx)	13.4	0.80
Fat content (%)	5.5	1.33
Protein content (%)	5.4	0.49
Lactose content (%)	4.7	0.26
Total solids content (%)	16.5	1.51

Milk fat

Coefficients

Predictor	Unstandardized coefficients			Collinearity statistics
	B	S.E.	P	VIF[*]
Intercept	3.96	3.63	0.276	
Refractive index	0.77	0.09	0.000	1.03
pH	-1.30	0.49	0.000	1.03

Bootstrap for Coefficients

Predictor	*B*	S.E.	P
Intercept	3.96	3.73	0.304
Refractive index	0.77	0.08	0.001
pH	-1.30	0.53	0.014

Milk protein

Coefficients

Predictor	Unstandardized coefficients			Collinearity statistics
	B	S.E.	P	VIF[*]
Intercept	-3.27	0.35	0.000	
Refractive index	0.58	0.02	0.000	1.24
Conductivity	0.24	0.04	0.000	1.24

Bootstrap for Coefficients

Predictor	*B*	S.E.	P
Intercept	-3.27	0.55	0.001
Refractive index	0.58	0.03	0.001
Conductivity	0.24	0.06	0.001

Milk lactose

Coefficients

Predictor	Unstandardized coefficients			Collinearity statistics
	B	S.E.	P	VIF*
Intercept	8.41	0.32	0.000	
Refractive index	-0.13	0.02	0.000	1.24
Conductivity	-0.50	0.04	0.000	1.24

Bootstrap for Coefficients

Predictor	*B*	S.E.	P
Intercept	8.41	0.39	0.001
Refractive index	-0.13	0.02	0.001
Conductivity	0.50	0.05	0.001

Milk total solids

Coefficients

Predictor	Unstandardized coefficients			Collinearity statistics
	B	S.E.	P	VIF[*]
Intercept	10.73	3.34	0.001	
Refractive index	1.16	0.09	0.000	1.24
Conductivity	-0.59	0.20	0.004	1.35
pH	-1.10	0.47	0.019	1.12

Bootstrap for Coefficients

Predictor	*B*	S.E.	P
Intercept	10.73	3.34	0.003
Refractive index	1.16	0.09	0.001
Conductivity	-0.59	0.20	0.006
pH	-1.10	0.48	0.023

Split-half cross validation

		Full data set	Split 1	Split 2
Fat	ANOVA significance (P≤0.05)	≤0.001	≤0.001	≤0.001
	R^2	0.250	0.349	0.158
	Significant coefficients in the model*	RI*, pH	RI, pH	RI
Protein	ANOVA significance (P≤0.05)	≤0.001	≤0.001	≤0.001
	R^2	0.779	0.794	0.765
	Significant coefficients in the model	RI, MEC**	RI, MEC	RI, MEC
Lactose	ANOVA significance (P≤0.05)	≤0.001	≤0.001	≤0.001
	R^2	0.379	0.409	0.354
	Significant coefficients in the model	RI, MEC	RI, MEC	RI, MEC
Total solids	ANOVA significance (P≤0.05)	≤0.001	≤0.001	≤0.001
	R^2	0.511	0.581	0.443
	Significant coefficients in the model	RI, MEC, pH	RI, MEC, pH	RI, MEC

*P≤0.05

Results

Prediction equations of milk quality traits:

Fat = 3.96 + 0.77 × RI - 1.30 × pH

Protein = -3.27 + 0.58 × RI + 0.24 × MEC

Lactose = 8.41 - 0.13 × RI - 0.5 × MEC

Total solids = 10.73 + 1.16 × RI - 0.59 × MEC - 1.1 × pH

Example
A milk sample with
✓**Refractive index = 14.0 °Bx**
✓**pH = 6.7**
✓**Electrical conductivity = 4.0 ms/cm**

... is expected to have
➢ **Fat = 6.0 %**
➢ **Protein = 5.8 %**
➢ **Lactose = 4.6 %**
➢ **Total Solids = 17.2 %**

Conclusions

- We can predict milk protein, lactose and total solids content using refractive index and milk electrical conductivity in sheep's milk

- Milk quality trait prediction models will help farmers and breeders breed the sheep that produce the best quality milk

- External validation of the models using milk produced from different
a) dairy sheep breeds
b) farming systems
c) time-points within the lactation

   will make the predictions more applicable

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Thank you for your attention...

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