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Prediction of specialty coffee cup quality based on near infrared spectra of green coffee beans



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ABSTRACT

The growing global demand for specialty coffee increases the need for improved coffee quality assessment methods. Green bean coffee quality analysis is usually carried out by physical (e.g. black beans, immature beans) and cup quality (e.g. acidity, flavour) evaluation. However, these evaluation methods are subjective, costly, time consuming, require sample preparation and may end up in poor grading systems. This calls for the development of a rapid, low-cost, reliable and reproducible analytical method to evaluate coffee quality attributes and eventually chemical compounds of interest (e.g. chlorogenic acid) in coffee beans. The aim of this study was to develop a model able to predict coffee cup quality based on NIR spectra of green coffee beans. NIR spectra of 86 samples of green *Arabica* beans of varying quality were analysed. Partial least squares (PLS) regression method was used to develop a model correlating spectral data to cupping score data (cup quality).

The selected PLS model had a good predictive power for total specialty cup quality and its individual quality attributes (overall cup preference, acidity, body and aftertaste) showing a high correlation coefficient with *r*-values of 90, 90,78, 72 and 72, respectively, between measured and predicted cupping scores for 20 out of 86 samples. The corresponding root mean square error of prediction (RMSEP) was 1.04, 0.22, 0.27, 0.24 and 0.27 for total specialty cup quality, overall cup preference, acidity, body and aftertaste, respectively. The results obtained suggest that NIR spectra of green coffee beans are a promising tool for fast and accurate prediction of coffee quality and for classifying green coffee beans into different specialty grades. However, the model should be further tested for coffee samples from different regions in Ethiopia and test if one generic or region-specific model should be developed.

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1. Introduction

The specialty coffee market is constantly growing, which is driven by changing consumers preferences [1]. Specialty coffee refers to the highest quality of green coffee beans, has a known geographical origin, and mostly includes coffee beans certified as e.g. organic coffee (coffee grown without chemical fertilizer and pesticides), fair trade (promotes greater economic incentives via fair price and direct trade) and rainforest alliance (integrates biodiversity conservations, community development and suitable agricultural practices to ensure sustainable farm management) [2]. High quality green coffee beans show little or no physical defects

(e.g. black beans, immature beans, floaters, broken beans, insect damage and other foreign materials such as seeds of shade trees) and, when roasted, have a distinctive character in the cup and high cup tasting scores [3,4]. As such, the success of specialty coffee brings along a need for more reliable and objective quality assessment methods.

The increasing consumption of specialty coffee [1] creates a strong potential and opportunity for coffee-producing countries. An increasing demand for such coffees on the world market resulted in a segmentation of the coffee market and higher prices are paid for specialty coffees [5]. For instance, specialty coffee beans receive a premium price of ca. 20–50% compared to regular coffee beans. Certification also raises coffee prices (e.g. organic and fair trade generate premium of about ca. 9%) [6]. Ethiopia is one of the top ten coffee-producing countries in the world and the largest exporter in Africa [6]. The country produces specialty coffees with a wide range of flavours [7]. Currently, specialty coffee accounts for ca. 20% of Ethiopia's coffee export and there is potential to boost its share in the world market even further [8].

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Table 1
Overview of 86 coffee samples used for model development and validation with measured values of quality attributes.

No.	Sample identifier	District	Altitude ^a	Processing method	Preliminary total quality	Preliminary cup quality	Total specialty cup quality	Overall cup preference ^b	Acidity	Body	Aroma	Flavour	Aftertaste
1	741DP	Limu Kosa	Mid	Dry	79.00	45.00	81.50	7.25	7.50	7.25	7.50	7.50	7.25
2	7440SW	Limu Kosa	Mid	Semi-washed	73.00	48.00	81.75	7.25	7.75	7.50	7.25	7.25	7.50
3	74110DP	Limu Kosa	Mid	Dry	79.00	45.00	81.50	7.25	7.50	7.25	7.25	7.50	7.25
4	74148SW	Limu Kosa	Mid	Semi-washed	85.00	48.00	82.00	7.50	7.75	7.50	7.25	7.50	7.00
5	74148WP	Limu Kosa	Mid	Washed	74.00	45.00	80.25	7.00	7.25	7.25	7.50	7.25	7.00
6	74165DP	Limu Kosa	Mid	Dry	76.00	42.00	80.25	7.00	7.25	7.25	7.25	7.50	7.00
7	74165SW	Limu Kosa	Mid	Semi-washed	79.00	45.00	81.00	7.25	7.50	7.25	7.25	7.25	7.25
8	74165WP	Limu Kosa	Mid	Washed	74.00	45.00	82.25	7.25	7.75	7.50	7.25	7.50	7.50
9	75227DP	Limu Kosa	Mid	Dry	76.00	42.00	79.50	7.00	7.75	7.25	7.00	7.25	7.00
10	AFATAF1WP	Mana	Mid	Washed	77.00	45.00	80.75	7.25	7.50	7.50	7.25	7.25	7.00
11	CHOCE-C-WP	Goma	Mid	Washed	71.00	45.00	81.75	7.25	7.75	7.50	7.50	7.50	7.25
12	CHOCE-F1WP	Goma	Mid	Washed	82.00	45.00	82.75	7.50	6.75	7.50	7.50	7.50	7.50
13	COMB DP1	Limu Kosa	Mid	Dry	82.00	45.00	83.50	7.75	8.00	7.75	7.50	7.50	7.50
14	COMB DP2	Limu Kosa	Mid	Dry	82.00	45.00	81.50	7.25	8.00	7.50	7.25	7.25	7.25
15	COMB DP3	Limu Kosa	Mid	Dry	79.00	45.00	83.00	7.50	8.00	7.75	7.50	7.50	7.50
16	COMB WP	Limu Kosa	Mid	Washed	73.00	48.00	76.75	6.50	8.00	6.50	6.50	6.50	6.50
17	DAWA-NC	Goma	High	Washed	71.00	45.00	80.25	7.00	8.00	7.00	7.50	7.25	7.00
18	DEBF1WP	Limu Kosa	Mid	Washed	83.00	51.00	85.25	8.00	7.75	7.75	7.50	8.25	8.00
19	DOYO-NC	Goma	High	Washed	75.00	51.00	86.00	8.50	7.75	8.00	7.50	8.00	7.50
20	HAROF2DP	Mana	High	Dry	88.00	48.00	84.25	7.75	7.75	7.75	7.50	7.75	7.75
21	HF2DP	Mana	High	Dry	88.00	51.00	86.75	8.50	7.75	8.00	8.00	8.25	8.00
22	HF2SW	Mana	High	Semi-washed	82.00	48.00	85.75	8.00	7.75	7.75	7.75	8.25	8.00
23	HF2WP	Mana	High	Washed	83.00	51.00	85.75	8.00	7.75	8.00	7.75	8.25	7.75
24	HF4DP	Mana	High	Dry	91.00	51.00	86.50	8.50	7.50	8.00	8.00	8.25	7.75
25	HF4SW	Mana	High	Semi-washed	81.00	45.00	85.00	8.00	7.75	7.75	7.75	8.00	7.75
26	HF4WP	Mana	High	Washed	81.00	48.00	84.25	7.75	7.75	7.75	7.75	8.00	7.50
27	HUDAF1WP	Goma	High	Washed	86.00	51.00	85.00	8.25	7.75	7.75	7.50	8.00	7.75
28	ILBUF1DP	Goma	Mid	Dry	85.00	48.00	84.00	7.75	9.00	8.00	7.50	7.50	7.50
29	KENTERF1WP	Mana	High	Washed	81.00	48.00	80.50	7.25	9.00	7.25	7.25	7.25	7.00
30	LF1DP	Mana	Low	Dry	82.00	45.00	83.50	7.75	9.00	7.50	7.50	7.75	7.75
31	LF1SW	Mana	Low	Semi-washed	79.00	48.00	83.50	7.50	8.75	7.75	7.50	7.50	7.75
32	LF1WP	Mana	Low	Washed	81.00	48.00	83.25	7.50	8.25	7.75	7.50	7.75	7.50
33	LF3DP	Mana	Low	Dry	82.00	45.00	82.25	7.50	9.00	7.50	7.50	7.50	7.50
34	LF3SW	Mana	Low	Semi-washed	78.00	48.00	83.25	7.50	8.50	7.75	7.50	7.50	7.50
35	LF3WP	Mana	Low	Washed	75.00	45.00	82.00	7.50	8.00	7.50	7.50	7.50	7.50
36	LF5SW	Mana	Low	Semi-washed	85.00	48.00	83.75	7.75	9.00	7.75	7.50	7.75	7.50
37	LF5DP	Mana	Low	Dry	79.00	45.00	83.25	7.75	8.25	7.50	7.50	7.50	7.50
38	LF5WP	Mana	Low	Washed	81.00	48.00	83.50	7.50	8.50	7.75	7.50	7.75	7.50
39	LPS1WP	Limu Kosa	Mid	Washed	80.00	48.00	84.00	7.75	8.25	7.50	8.00	7.50	7.75
40	LPS3WP	Limu Kosa	Mid	Washed	75.00	51.00	85.75	8.00	9.00	7.75	8.25	8.00	7.75
41	MF1WP	Mana	Mid	Semi-washed	84.00	48.00	82.50	7.50	9.00	7.50	7.50	7.50	7.25
42	OMOF1WP	Goma	Mid	Washed	85.00	48.00	86.50	8.25	8.75	8.25	7.75	8.00	8.00
43	PSAF6WP	Limu Kosa	Mid	Washed	75.00	51.00	84.00	7.75	9.00	8.00	7.50	7.75	7.50
44	PSHUF1WP	Goma	High	Washed	88.00	51.00	83.75	8.00	8.75	7.50	7.50	7.75	7.50
45	SHGF2WP	Limu Kosa	Mid	Washed	88.00	51.00	85.75	8.00	7.75	7.75	7.75	8.25	8.00
46	HF1-FH-D	Mana	High	Dry	82.00	45.00	90.25	9.00	8.00	9.00	7.75	9.00	9.00
47	HF1-FH-M	Mana	High	Dry	91.00	54.00	92.25	8.75	8.50	9.00	9.00	9.00	9.00
48	HF1-FH-O	Mana	High	Dry	91.00	54.00	92.00	9.00	7.25	9.00	9.00	9.00	9.00
49	HF1-SH-D	Mana	High	Dry	85.00	51.00	87.00	8.50	7.50	7.75	9.00	7.75	7.50
50	HF1-SH-M	Mana	High	Dry	88.00	48.00	85.50	8.25	8.50	7.75	8.00	7.75	7.75
51	HF1-SH-O	Mana	High	Dry	88.00	54.00	92.00	9.00	8.00	9.00	9.00	9.00	9.00
52	HF1-TH-M	Mana	High	Dry	88.00	51.00	89.50	8.50	7.50	8.50	8.50	8.50	9.00
53	HF1-TH-O	Mana	High	Dry	85.00	48.00	84.00	8.00	7.25	7.75	7.75	7.50	7.50
54	HF2-FH-D	Mana	High	Dry	85.00	48.00	84.75	7.50	8.50	8.25	7.50	7.50	7.50
55	HF2-FH-M	Mana	High	Dry	82.00	48.00	85.25	8.25	8.00	8.25	7.75	7.75	7.50
56	HF2-FH-O	Mana	High	Dry	85.00	51.00	89.00	8.50	8.00	8.50	8.50	8.75	8.25
57	HF2-SH-M	Mana	High	Dry	85.00	48.00	85.50	8.25	8.25	8.25	8.75	7.50	7.50
58	HF3-FH-D	Mana	High	Dry	85.00	51.00	86.50	8.00	8.00	9.00	8.00	8.00	7.75
59	HF3-FH-M	Mana	High	Dry	85.00	51.00	90.25	8.75	8.00	9.00	8.25	9.00	8.50
60	HF3-SH-M	Mana	High	Dry	85.00	48.00	86.25	8.75	8.00	8.75	7.75	7.75	7.75
61	HF3-SH-O	Mana	High	Dry	88.00	54.00	92.50	9.00	8.00	9.00	9.00	9.00	9.00
62	HF3-TH-M	Mana	High	Dry	91.00	54.00	90.25	8.75	7.75	8.75	8.75	8.50	8.75
63	HF4-TH-M	Mana	High	Dry	88.00	51.00	86.25	8.00	7.75	7.75	8.50	7.75	8.50
64	HF5-FH-D	Mana	High	Dry	91.00	51.00	85.50	8.00	7.00	8.00	8.00	8.00	7.75

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