SMART NIRS DISCRIMINATION OF FREEZE-DRIED VEGAN AND MEAT BURGERS

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I. INTRODUCTION

Meat consumption has always been the subject of religious or behavioral constraints to which has been added a widespread concern for its sustainability which has favored the consumption of vegan products like meat. The aim of the present study was to ascertain whether an optic device can authenticate the nature of a burger as meaty or veggie [1]. For this purpose, in the framework of the Eit Food project (2021-2022) “Improving juiciness of plant-based meat alternatives” a smart NIR was applied to distinguish between a set of self-produced or commercial vegan burgers and meat burgers.

II. MATERIALS AND METHODS

Three types of burgers divided into seventeen batches were analysed as follows: two batches of one commercial vegan type purchased from the market (C, n = 24); thirteen different self-produced vegan burgers (P01-P13, n = 156) and two batches of self-produced meat burgers (M, n = 24; 60 % beef, 40 % pork). Before the optic scans the raw samples were homogenised in a mixer (Moulinette 800W; 600 rpm) for 20 s, freeze-dried and then ground. The samples were examined in triplicate by a SCÏO^{TM} v. 1.2 molecular sensor (Consumer Physics Inc., Tel Aviv, Israel), which is a smart device that operates flashing a blue light and receiving the reflectance radiation above the range 740-1070 nm, i.e., 331 points differentiated from a standard blank, checked at the beginning of the analysis session. A first classification of the three types was carried out by the SCÏO Lab proprietary software using a Random Forest (RF) algorithm on the log 2nd derived *spectra*. A second classification was performed with the WinISI-III software. In this case a PLSDA was conducted on the PLS predictions of the three types calibrating the standardized 2nd derived log(1/R) *spectra* on the incidence matrix, and then submitted to a cross-validated MDA by the XLSTAT software.

III. RESULTS AND DISCUSSION

The optical classification of the nature of the burgers reached a very highly accuracy (Table 1). Oriented toward an animal consensus (M-Meat) the sensibility of the test was 100 % for the RF reduced to 90.5 % (significantly lower) for the PLSDA analysis. This last feature seemed more realistic as fruit of a true cross-validation. Otherwise, the specificity, i.e., the correct classification of the vegan burgers (C & P) was high at 98 % and 100 % respectively for RF and PLSDA. As part of the examined NIR *spectra* the imprint of the vegan burgers was more pronounced. Thus, the accuracy in immediate discovery of a vegan burger among a mixed cohort was higher than for a meaty burger. This fact could depend on the unbalancing of samples. Where the commercial burgers were compared to meat burgers, they were identified without error according to the RF and confused at 9.5 % (100-90.5 %) according to the PLSDA. The prototypes were identified without a doubt by all the methods. This result highlights a progress in the commercial type as mimetic of the real meat burger that has not yet been achieved with the prototypes.
When all the three groups were individually elaborated (Table 2) a superiority of the algorithm PLSDA *versus* RF was evident because the average error rate was 21.3 % *vs* 37.8 %.

Table 1. Percentage and number of the samples correctly classified in the three types of burgers according the two algorithms (P < 0.0001 for the 4 models).

Type	*Spectra* (n)	Random Forest				PLSDA			
		M (n)	C & P (n)		Total (%)	M (n)	C & P (n)		Total (%)
M-Meat	63	63	-		100[a]	57	6		90.5[b]
C & P	570	11	559		98.0[a]	-	570		100[a]
		M	C	P	Total	M	C	P	Total
M-Meat	63	63	-	-	100[a]	57	6	-	90.5[b]
C-Commercial	102	-	94	8	92.0[b]	-	101	1	99.0[a]
P-Prototype	468	-	-	468	100[a]	-	3	465	99.4[a]

a, b; P = 0.05; on the row

Table 2. Error rate % in individual classification analysis of the three groups of burgers according the two algorithms.

Algorithms	M	C	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	Mean
PLSDA	2	0	56	36	54	8	7	12	22	0	0	33	62	26	23	21.3
RF	0	0	100	75	50	25	14	39	60	8	43	43	100	25	23	37.8

The maximum differences vegan\meat in the transformed *spectra* were localized at 925 and 942 nm (Figure 1). However, given the complex structure of the burgers there exist several discriminating wavelengths. In fact, a two-terms stepwise regression selected two different wavelengths, namely 902 and 1052 nm, and reached an R^2 = 0.78, while the 11-terms PLS equation using 160 points reached an R^2 = 0.88 respectively.

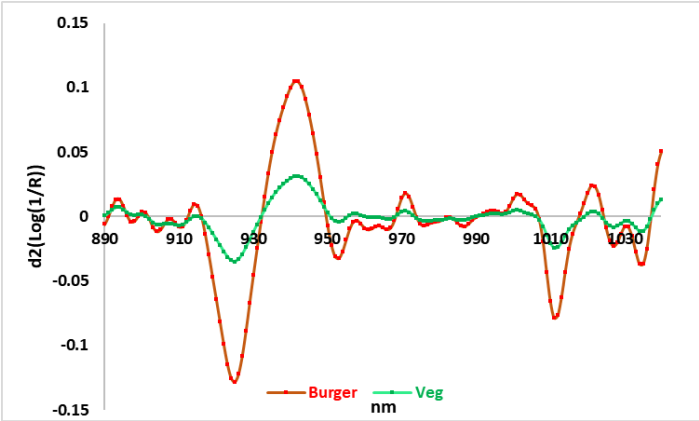

Figure 1. Plot of the average transformed NIR *spectra*

IV. CONCLUSION

NIRS studies and applications on the vegan\meat burger discrimination are lacking. The present work confirms previous finding on Halal [2] and game meat [3] highlighting that a NIRS optic instrument can accurately distinguish a vegan burger from a meaty one having previously proceeded to homogenisation and freeze-dry the samples. In fact, on the as-is it was not possible to reach an acceptable accuracy due to the complex and coarse structure.

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