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Optimization of the Moroccan traditional cured meat (*Khlia*) using an experimental design method

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Abstract

This study aimed at improving the nutritional and organoleptic quality of traditional Moroccan cured meat products named "*Khlia*" using an experimental Plakett-Burman design. The idea was to control some factors that impacts the formulation, nutritional and organoleptic quality especially salt and spices. Despite being aware that consumers are unwilling to compromise their favorite taste for the sake of health, we have endeavored to meet their requirements. For that, the concentration of salt, garlic, coriander, cumin, and caraway were distributed to five variables by Plackett-Burman design. *Khlia* formulations were made and twelve combinations, which were run in triplicate, developed through an experimental design process, and stored one-year sensory. The analysis was made by two statistical tools Plackett-Burman design by JMP 5. Results showed that the property of some spices to preserve the original taste of the products after one-year of preservation were in favor of interactions between some spices that could be powerful in the preservation and sensory quality even with less salt. Rancid-free products were associated with either high salt and/or spice, which confirmed the possibility of partially dispensing salt, depending on the spice's concentrations. The concentrations of variables able to change the organoleptic quality and even extend the shelf life were deeply examined. Hence, new formulations were adopted since the most significant factors were determined.

Keywords: Optimization, cured meat, traditional Khlia, preservation, salt, garlic, coriander, cumin, caraway, experimental design

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1. Introduction

The consumption of meat products is largely widespread around the world and the society required clean label or naturally preserved meat products. Different salted meat products are famous in North Africa [1]. They can be divided into two groups dry and wet cured meat products [2]. Traditional dry meat products presents one of culinary heritages which are popular among consumers due to their strong flavor characteristics and desirable complex taste [3].

Strong test owing to the free fatty acid oxidation and lipolysis during the drying process [4] and synergistic effect of fat, free amino acids, spices extracts flavors [5]. Therefore, several dry meat products throughout the world particularly "*Khlia"* and "*Kaddid*" have been studied with a view to modernizing and improving their process [4]. The art of preserving meat in the past by sun drying and salting is a cultural practice in several countries and *Kaddid* is one of traditional cured meat added to fat. Indeed, "*Khlia*" is a typical Northern African cured meat product, obtained from salted-dried meat, which is cooked and conditioned in fat, or in olive oil to obtain diet *Khlia* [6]. *Khlia*, is also prepared by seasoning the fresh meat with salt and spices and sun drying. All meat parts of the carcass can be used particularly thorax part, and then cut into pieces to facilitate spices and salt diffusion and drying. A mixture of spices, garlic and salt is sprinkled into the cuts. The cut meat is then exposed to drying by hanging meat in sun until water activity removal [4]. The organoleptic quality of meat products is affected by many factors including raw material, ingredients concentrations and salting. In this sense, the salt has become a big issue in meat industry since salt intake is correlated to hypertension and other heart diseases incidence, resulting in food salting reduction. Until now, *Khlia* is usually prepared with a homemade process at traditional scale, and the product has not been scientifically studied enough. Despite attempts at its industrialization in the country, the production process is still based on the traditional method slightly modified, using UV irradiation to ensure microbial growth and pathogens elimination. Thus, the purposes of this work were the valorization of Moroccan cultural heritage of some traditional meat products through the optimization of *Khlia* preparation with the experimental design method. This is an innovative approach to control the conditions of preparation of this traditional product and avoid the potential risks that they may arise, reducing the use of salt, and to improve their nutritional and organoleptic quality, which will lead to the promotion of these Moroccan products on the market, nationally and internationally.

2. Materials and Methods

2.1. Material sampling and Khlia preparation

To select the variables, which affect the final formulation of *Khlia*, and before starting sample collection, a field study was undertaken with the traditional producers and households regarding the principal ingredients used and the preparation steps of the product. As described above, one of the main ingredients of *Khlia* is dried and salted meat (*Kaddid*). Through a questionnaire conducted with 60 people randomly chosen in Fez city in Morocco, it appears that *Khlia* is a traditional Moroccan local product, prepared with red meat (ovine, bovine, camelina or goat). The formulation of meat products uses three traditional preservation techniques: salting, drying, and cooking. This makes the products capable of being preserved for more than one-year. The meat is seasoning, salted, and marinated then dried for seven days before cooking with animal fats from the adrenal part and olive oil. Thus, five factors (salt (X_1), garlic (X_2), coriander (X_3), cumin (X_4) and caraway (X_5) concentrations) were studied for the improvement of dried salted meat product (*Kaddid*) in Morocco.

2.1.1. Kaddid preparation

Kaddid is a salted and dried meat product used as a principal ingredient of *Khlia* (cured meat product), also in some traditional dishes. *Kaddid* is always prepared using beef, lamb, or even camel meat. Meat was cut into boneless of 6-10 cm, and every 100 g of beef meat was mixed to the selected variables (salt, garlic, coriander, cumin and caraway) using statistic. Plakett-Burman design for the distribution of the five variables in 36 combinations for the formulation of *Kaddid*, before being left in the oven then thoroughly dried at 60 °C during 24 hours. Usually, the traditional drying process consists of exposing meat to sun, but in this study the natural factors was avoided in the experiment design (Burman plaquette) for better variable control [7].

2.1.2. Khlia preparation

Using the previously prepared dried meat (*Kaddid*), each sample of 100 g was mixed with 20 g of kidneys fat, 20 mL of olive oil, and 20 ml of water. The cooking temperature in the hot plate was maintained at 80 °C until water elimination, and then the obtained product was ready for a storage period for one-year.

2.2. Experimental design

It is well known that many factors can significantly influence meat conservation. Depending on the literature and field investigation, five variables were selected especially the concentrations, in g/kg, of the following ingredients: Salt (NaCl): X_1, Garlic (*Allium sativum*): X_2, Cor (*Coriandrum sativum*): X_3, Cum (*Cuminum cyminum L*): X_4, and Car (*Carum carvi L*): X_5. This study was performed according to factorial experiment design where the calculation of polynomial coefficients model has been accomplished through the "least squares" method with the use of coded variables. In fact, the act of replacing the natural variables by coded variables allows for the same domain of variation for each factor (between -1 and +1) and hence being able to compare the effect of factors among themselves. The lowest level is coded -1 while the highest level is coded +1 (Table 1).

2.3. Consumer appreciation of Khlia

The consumer test panels were performed at the Faculty of Sciences and techniques (Fez city) and a minimum of 60 consumers (> 18 years old) were targeted to assess the mixtures of meat products with the variables. Twelve dried cooked meat products (*Khlia*) which were run in triplicate preserved one-year were tested. Thirty-six mixtures were served to consumers, hot with bread and one apple to neutralize the mouth after testing of each sample. Twelve sample were served to each consumer to control taste consumer. Prior *Khlia* evaluating and testing, all consumers received the samples in the same way, blind-coded for unbiased testing. Each sample was evaluated by the panelists, scored from1 to 10, depending to the questions extremely for the following attributes, **Color**: the panelists scored color (the intensity of brown color in *Khlia*?), **TEXT**: Texture

(Homogeneous or not ?), **Brian** : Brightness (Homogeneous or not ?), **IO**: Odor intensity (about the perceived strength of meat product odor?), **AA**: Appreciation of Aroma (about intensity of aroma?), **IGr**: Fat taste intensity (about intensity of fats in the meat products), **I Sel**: saltiness intensity(about intensity of salt or the sensation of sodium chloride in the meat products), **I Ail**: garlic taste intensity(about intensity of garlic in the meat products), **I Cum**: Cumin taste intensity (about intensity of cumin in the meat products), **I Carv**: Caraway taste intensity (about intensity of caraway in the meat products), **I Cor**: coriander taste intensity (about intensity of coriander in the meat products), **Sav I**: pleasant of flavor (if obviously full of flavor?), **Sav A**: Pleasant after taste (about intensity of after taste 1 min after swallowing), **Ran**: Rancidity (about intensity of lipids oxidation). The presence of some attribute or not, on 0-10 unstructured scale, it depended on the question which the 0 score on ascending scale of each attribute.

2.4. Statistical Analysis

Obtained data were analyzed using JMP statistical software (version 2011). Sensory analysis of the studied variables was assessed through ANOVA test to compare the means results. The interaction between variable were assessed by JMP and the correlation between sensory attributes by Principal component analysis with past software. Plakett-Burman mixture design was used to screen the significant factors each variable was tested at low (-1) and high (+1) concentration. The experimental Plakett-Burman mixtures design was analyzed by JMP software, and five assigned variables were studied in 36 experimental designs, *IO: Odor intensity, AA: Appreciation of aroma, Sav I: pleasant of flavor, Sav A: Pleasant after taste, Ran: Rancidity,* were taken as responses. The factors that affect the formulation of traditional cured meat products were found to have high and significant (P-value < 0.05) impact on Sensory attributes.

3. Results and discussion

3.1. Validation of the mathematical model relating the studied factors

Plackett-burman design is powerful statistical tool for selecting the significant factors and to investigate the interactions among the five selected factors. The results are listed in Table 3. To be able to conduct the statistical calculations and prevent that n = p, it is necessary to make replication when n is the number of tests and p is the number of estimated parameters starting from the model, i.e., the number of the model's coefficients. This is the case in this study (Y_{IO}, Y_{AO}, $Y_{AA,}$ $Y_{Sav\ I,}$ Y_{SavA} and Y_{Ran}). a_0, a_1... a_5 are the mathematical coefficients of the model. a_{ij}. X_i X_j corresponds to the interactions. n = 36: the number of realized experiments. P the number of estimated parameters from the model.

3.2. Validation of experimental models by statistical analysis

To study the suitability and significance of the model, a variance analysis (ANOVA) is performed. The *p*-values are used to verify the meaning of the corresponding coefficient and the smaller the *p*-values, the greater the meaning of the corresponding coefficient. The independent and response variables are fitted to linear, quadratic, and special cubic models. Sensorial analyses are determined to assess the efficiency of the spices used on the conservation of *Khlia* during storage period (Table 3). The Plackett-Burman is chosen, because it presents a perfect experimental design for screening and mixtures 100 % of total variance (determination coefficient R^2 = 1.000, R^2 adjusted = 1.000), indicating that all response functions adequately fit the experimental data, and the models can be used for predictive purposes of meat products formulation. According to Table 3, all models are highly significant as indicated by the low P-values and high F-values for (Y_{IO}, Y_{AO}, Y_{AA}, Y_{SavI}, Y_{SavA}, and Y_{Ran}) by looking at calculated F values and probability values to examine the relative importance of the main effects and their interactions with statistical significance ($P \leq 0.05$). The main factors Salt (X_1), Garlic (X_2), Coriander (X_3) Cumin (X_4), Caraway (X_5) that exceed the baseline are significant at the level of 0.05. The factors affect the formulation, caraway (X_2) coriander (X_3) have the most significant effect on the conservation of drying meat, followed by cumin (X_4). Thus, the application of the mixture has established the best proportion between spices and salt for the quality preservation during one-year alteration.

3.3. Drying Meat optimizations by experimental design

3.3.1. Rancidity

Results of rancidity test are summarized in Table 2. As shown, the mathematical model is written as follows and has the form: $Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$ since F (observed) > F (theoretical), therefore the variability of model hypotheses is accepted.

$$\mathbf{Y_{Ran} = 2.19 - 0.33X_1 - 0.79X_2 + 0.32X_3 + 0.49X_4 - 0.23X_5}$$

Since Y_{Ran} represents rancidity of traditional meat products after one-year of preservation at room temperature, related to the concentration of which has the most important effect, the mathematical effect could be adapted to find the relationship between the rancidity and the variables. Subsequently, Y_{Ran} represents rancidity and since the aim is to improve the organoleptic quality and improve the preservation against germs and lipid oxidation of traditional meat products (*Khlia*), it is the garlic and cumin concentrations, which present high effect on rancidity. The study of factors and the interactions between variables also confirm the high effect of garlic and cumin on rancidity taste of cured meat products (Khlia) as shown in Table 4. The significant influence of X_2 is evident, mainly in relation to the caraway level in mixtures, which vary from (+1, -1) g per kg corresponding to (30, 20 g per kg). The absence of rancidity in certain mixtures after one-year is particularly noteworthy, especially considering traditional meat products prepared with fats that are prone to fungal attacks leading to rancidity. This resilience is attributed to the presence of garlic and cumin, as well as salt, and/or interactions between the spices, with some demonstrating antifungal activity. Meat products rancidity is defined as food spoilage [8], due to the lipids and fats oxidation particularly unsaturated fatty acids which could

results the formation of harmful compounds, off-odors and off flavors. Rancid-free products are often associated with either high salt and/or spice, which confirms the possibility of partially dispensing salt, depending on the spice's concentrations. The concentrations of spices factors able to change the organoleptic quality and even extend the shelf-life [9].

3.3.2. Odor pleasant

The results of this odor pleasant test are summarized in Table 5 which represents the results where F (observed) > F (theoretical), therefore the variability of model hypotheses is accepted:

$$\mathbf{Y_{OA} = 6.15 + 0.05X_1 - 0.12X_2 - 0.06X_3 - 0.22X_4 + 0.31X_5}$$

Y_{OA} represents odor pleasant of meat products related to the concentration of which has the most important effect. The mathematical effect could be adapted to find the relationship between the odor pleasant and the variables. Since the aim is to improve their organoleptic quality of traditional meat products one of the attributes that have to improve (odor pleasant), it is the caraway concentration which has effect. The study of factor and the interactions between variables and odor.

3.3.3. Appreciation of aroma

The results of appreciation of aroma test are summarized in Table 6.

$$\mathbf{Y_{AA} = 6.74 + 0.05X_1 - 0.21X_2 - 0.15X_3 + 0.11X_4 + 0.17X_5}$$

As can be verified, we find that F (observed) > F (theoretical), implying that the variability of the model's assumptions is accepted. Y_{AA} represents the appreciation of aroma of meat products related to the concentration of which has the most important effect, the mathematical effect could be adapted to find the relationship between aroma and some variables. Y_{AA} is one of the attributes that affect the improvement of organoleptic quality of traditional meat products; that is cumin, garlic and salt concentration which have effect on meat products appreciation of aroma Folioing the placket design experimental conditions. The study of the contribution of the factors to the perception of the aroma of the cured meat products under the experimental conditions and according to Table 6 clearly shows that the great influence of X1, X2 and X5, corresponding to the level of salt in the mixtures, can take on the value of (+1, -1) g per kg corresponding to 50, 30 g per kg. Previous studies demonstrated that the ingredients and processing parameters on volatile compounds responsible for aroma of these compounds results in lipids oxidation and Maillard reaction [10, 11]particularly sulfur and nitrogen composition impact aroma [2].

3.3.4. Odor intensity

The results of odor intensity test are summarized in Table 7. As can be shown, it can be noticed that F (observed > F (theoretical), therefore the variability of model hypotheses is accepted.

$$\mathbf{Y_{OI} = 6.31 + 0.30X_1 + 0.11X_2 - 0.16X_3 + 0,06\ X_4 + 0.27X_5}$$

Y_{OI} represents odor intensity of meat products related to the concentration of which has the most important effect; the mathematical effect could be adapted to find the relationship between aroma and some variables. It is known that the concentration of cumin, garlic and salt has a great effect on the intensity of the smell of traditional meat products. The study of factors effects odor intensity of cured meat products with experimental conditions and experimental mixtures. Table 7 shows the effect of factors. It can clearly be seen the great influence of X_4, corresponding to the level of caraway in mixtures may take value of (+1, -1) g per kg corresponding to 10, 5 g per kg. Some volatile compounds responsible for odor some of these compounds results of lipids oxidation and Maillard reaction [10] particularly sulfur and nitrogen composition impact odor [2] also the spice contribution in odor of cured meat products mean while extend the shelf life due to its antioxidant potential [3, 12].

3.3.5. Pleasant of flavor

The results of pleasant of favor test are summarized in the following Table 8. According to Table 8, it is noticed that F (observed) > F (theoretical), therefore the variability of model hypotheses is accepted.

$$\mathbf{Y_{Sav\ I} = 6.23 - 0.09X_1 - 0.38X_2 - 0.02X_3 + -0,08X_4 - 0.09X_5}$$

Since $Y_{Sav\ I}$ represents the meat products Pleasant of flavor related to the concentration of which has the most important effect, the mathematical effect could be adapted to find the relationship between flavor and some variables. The traditional consumer acceptance of *Khlia* due to their unique flavor which in this work presents one of the important sensory, attributes also the unique features of ripening process [13] and lipids oxidation during its length preservation. The achievement of the optimum flavor characteristic of cured meat products in this study is related to the garlic concentration. The differences and the intensity of flavor could be due to Maillard reactions products and primary lipid degradation associated with beef [14, 15]. In this study parameters are fixed due to the experimental design in all samples but the concentration of each variable could react differently with the fixed parameters and gave greater flavors development and better flavors compounds to some formulations than others. Since cured meat products are preserved one-year is one of the big challenge to protect the formulations from the development of off-flavors that related some time with its length and an intensification treatment of the cooking temperature or over-cooking [16]. A desirable flavor is important sensory attribute governing the consumptions of cured meat products [17].

3.3.6. Pleasant after taste

The results of this pleasant after taste test are summarized in the following Table 9. From the results presented in Table 9, it is noticed that F (observed) >F (theoretical), therefore the variability of model hypotheses is accepted.

Table 1. Factorial experiment design

Factor and code	Level (g/kg)	Coded level
NaCl (X_1)	30	-1
	50	+1
garlic (X_2)	20	-1
	30	+1
Cor (X_3)	20	-1
	25	+1
Cum (X_4)	5	-1
	10	+1
Car (X_5)	5	-1
	10	+1

Table 2. Estimated parameters of rancidity (Ran)

Term	Estimate	Std. Erro	T ratio	Prob>|t|
Intercept	2.19	0.40	5.47	< 0.0001*
NaCl	-0.33	0.40	-0.82	0.41
Garlic	-0.79	0.40	-1.98	0.06
Cor	0.32	0.40	0.80	0.43
Cum	0.49	0.40	-1.22	0.23
Car	-0.23	0.40	-0.59	0.56

Table 3. Design data of coded variables NaCl (X_1), Garlic (X_2), Cor (X_3), Cum (X_4), Car (X_5).

N° Exp	Coded level	NaCl	Garlic	Cor	Cum	Car	IO	AO	AA	Sav I	Sav A	Ran
1	+++--	50	25	30	10	10	6.25	6.75	7.00	6.67	6.33	3.50
2	-+-++	30	25	20	5	5	5.00	5.00	5.00	6.00	5.00	1.00
3	-+++-	30	25	30	5	10	5.75	6.00	6.67	6.50	6.20	2.29
4	--+-+	30	15	30	5	10	7.00	6.00	5.00	5.43	5.14	2.17
5	+-+++	50	15	30	5	5	5.00	6.00	6.00	6.00	5.00	0.00
6	+++--	50	25	30	10	10	6.00	6.50	7.00	7.50	6.33	3.33
7	+-+++	50	15	30	5	5	6.00	6.00	6.00	5.00	6.00	0.00
8	+++++	50	25	30	5	5	7.00	7.00	9.00	8.00	7.00	7.00
9	---+-	30	15	20	5	10	8.67	8.33	6.33	5.67	7.00	0.00
10	+--+-	50	15	20	5	10	5.33	5.00	6.00	6.00	6.67	5.00
11	+-+++	50	15	30	5	5	6.00	4.80	6.40	7.00	5.80	0.00
12	+---+	50	15	20	10	5	5.67	5.17	5.17	6.25	3.60	0.00
13	+---+	50	15	20	10	5	5.00	4.00	5.17	ND	ND	0.00
14	--+-+	30	15	30	10	5	7.00	6.50	5.00	5.43	5.00	0.00
15	-+-++	30	25	20	5	5	5.00	6.00	6.00	7.50	6.50	5.00
16	--+--	30	15	30	10	10	7.00	5.00	5.00	6.00	6.00	0.00
17	--+--	30	15	30	10	10	7.00	7.00	6.00	6.00	6.00	1.00
18	-+++-	30	25	30	5	10	5.80	5.90	6.20	6.11	6.40	2.40
19	+++++	50	25	30	5	5	6.00	6.00	7.00	7.00	6.00	7.00
20	++---	50	25	20	10	10	6.50	6.50	5.67	6.20	6.20	1.33
21	+--+-	50	15	20	5	10	5.33	6.00	6.00	6.00	ND	5.00
22	+---+	50	15	20	10	5	5.00	5.00	5.17	ND	ND	0.00
23	-+--+	30	25	20	10	5	5.50	5.67	5.50	6.50	6.00	3.00
24	-+--+	30	25	20	10	5	5.50	5.67	5.67	6.25	5.67	3.33
25	+++--	50	25	30	10	10	6.50	7.00	8.00	6.00	5.33	0.00
26	--+--	30	15	30	10	10	7.67	5.67	4.50	6.00	6.00	3.00
27	++---	50	25	20	10	10	6.83	6.50	5.67	6.20	6.20	1.33
28	-+++-	30	25	30	5	10	6.00	5.67	6.00	6.33	6.50	0.00
29	---+-	30	15	20	5	10	7.00	8.00	8.00	5.67	7.00	0.00
30	+++++	50	25	30	5	5	7.67	8.00	8.00	6.33	7.67	0.00
31	-+-++	30	25	20	5	5	7.00	7.00	7.00	7.00	7.00	6.50
32	--+-+	30	15	30	10	5	7.00	6.00	5.50	5.43	5.50	2.00
33	+--+-	50	15	20	5	10	5.33	7.00	6.00	6.00	0.00	0.00
34	-+--+	30	25	20	10	5	6.50	5.25	6.75	7.00	7.00	6.67
35	---+-	30	15	20	5	10	8.67	7.00	7.00	5.67	7.00	7.00
36	++---	50	25	20	10	10	6.83	6.50	5.67	6.00	6.20	0.00

Table 4. Factors effect and interactions on the rancidity of Khlia

Term	Estimate	Lenth's t-ratio	P-value of the Observations	Simulated P-value
Garlic	0.791944	1.74	0.0888	0.8902
Cumin	0.486944	1.07	0.2800	1.0000
NaCl	-0.329722	-0.73	0.4576	1.0000
Cor	-0.318611	-0.70	0.4714	1.0000
Car	0.235833	0.52	0.6157	1.0000
Garlic*cum	-0.105237	-0.23	0.8157	1.0000
Garlic*NaCl	0.373094	0.82	0.4040	1.0000
Cum*NaCl	0.756168	1.66	0.1037	0.9272
Garlic*Cor	0.499513	1.10	0.2685	1.0000
Cum*Cor	-0.536615	-1.18	0.2382	0.9994
NaCl*Cor	0.171183	0.38	0.7132	1.0000

Table 5. Estimated parameters of odor pleasant (AO)

Term	Estimate	Std. Erro	T ratio	Prob > |t|
Intercept	6.15	0.15	40.04	< 0.0001*
NaCl	0.05	0.15	0.35	0.73
Garlic	-0.12	0.15	-0.80	0.43
Cor	-0.06	0.15	-0.40	0.69
Cum	-0.22	0.15	-1.45	0.15
Car	0.31	0.15	2.04	0.05

Table 6. Estimated parameters of Appreciation of aroma (AA)

Term	Estimate	Std. Erro	T ratio	Prob>|t|
Intercept	6.74	0.13	52.43	<0.0001*
NaCl	0.18	0.13	1.40	0.17
Garlic	-0.21	0.13	-1.65	0.10
Cor	-0.15	0.13	-1.18	0.24
Cum	0.11	0.13	0.87	0.38
Car	0.16	0.13	1.29	0.20

Table 7. Estimated parameters of Odor intensity (IO)

Term	Estimate	Std. Erro	T ratio	Prob > |t|
Intercept	6.31	0.15	40.59	<0.0001*
NaCl	0.30	0.15	1.93	0.06
Garlic	0.11	0.15	0.72	0.47
Cor	-0.16	0.15	1.72	0.29
Cum	0.06	0.15	0.39	0.69
Car	0.27	0.15	1.72	0.09

Table 8: Estimated parameters of Pleasant of flavor (Sav I)

Term	Estimate	Std. Erro	T ratio	Prob>|t|
Intercept	6.23	0.09	67.15	<0.0001*
NaCl	-0.09	0.09	-1.06	0.30
Garlic	-0.38	0.09	-4.08	0.0003*
Cor	-0.02	0.09	-0.28	0.78
Cum	-0.08	0.09	-0.91	0.37
Car	-0.09	0.09	-1.04	0.30

Table 9. Estimated parameters of Pleasant after taste (Sav A)

Term	Estimate	Std. Erro	T ratio	Prob>|t|
Intercept	6.05	0.12	50.11	< 0.0001*
NaCl	0.11	0.12	0.93	0.36
Garlic	-0.26	0.12	-2.13	0.04
Cor	0.04	0.12	0.32	0.75
Cum	-0.34	0.12	-2.87	0.008
Car	0.27	0.12	2.23	0.034

Table 10. Results of tasting analysis

Formula	Cl	TEXT	Brian	IO	AO	AA	I Gr	I sel	I aïl	I cum	I carv	I cor	Sav I	Sav A	Ran
1	7.25	7.75	7.75	6.25	6.75	7.00	7.00	7.50	6.50	7.50	7.00	8.00	6.67	6.33	3.50
2	5.00	5.50	7.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	4.50	6.00	5.00	1.00
3	7.00	7.00	6.67	5.75	6.00	6.67	6.33	5.67	4.80	6.00	1.75	2.67	6.50	6.20	2.29
4	7.00	6.00	5.33	7.00	6.00	5.00	7.25	5.83	5.17	7.33	5.25	5.00	5.43	5.14	2.17
5	6.00	5.00	5.00	5.00	6.00	6.00	7.00	5.00	5.00	5.00	5.00	6.00	6.00	5.00	0.00
6	8.00	8.00	7.33	6.00	6.50	7.00	7.50	6.50	6.33	7.67	6.50	8.00	7.50	6.33	3.33
7	5.00	5.00	5.00	6.00	6.00	6.00	7.20	5.00	5.50	4.33	4.33	5.33	5.00	6.00	0.00
8	7.00	9.00	5.00	7.00	7.00	9.00	7.00	7.00	6.00	5.00	7.00	7.00	8.00	7.00	7.00
9	8.00	7.50	7.33	8.67	8.33	6.33	7.00	7.33	7.00	7.33	7.33	7.00	5.67	7.00	0.00
10	6.00	6.00	5.33	5.33	5.00	6.00	6.00	7.33	5.00	6.00	5.67	5.00	6.00	6.67	5.00
11	6.40	5.80	7.40	6.00	4.80	6.40	7.00	6.00	3.00	6.00	6.00	6.00	7.00	5.80	0.00
12	5.83	6.33	5.75	5.67	5.17	5.17	5.50	6.17	5.83	6.00	7.00	6.00	6.25	3.60	0.00
13	5.83	5.00	7.00	5.00	4.00	5.17	5.50	6.17	6.00	6.00	7.00	5.00	ND	ND	ND
14	7.00	6.33	6.00	7.00	6.50	5.00	7.25	5.83	5.17	7.33	5.00	5.00	5.43	5.00	0.00
15	6.50	7.00	5.00	5.00	6.00	6.00	8.00	5.00	6.00	7.00	7.00	5.50	7.50	6.50	5.00
16	8.00	5.33	6.00	7.00	5.00	5.00	6.00	7.00	5.00	7.00	4.00	7.00	6.00	6.00	0.00
17	5.00	7.00	7.00	7.00	7.00	6.00	7.00	7.00	6.00	6.00	7.00	6.00	6.00	6.00	1.00
18	6.80	6.70	6.56	5.80	5.90	6.20	6.30	5.30	4.20	5.20	1.33	2.88	6.11	6.40	2.40
19	7.00	9.00	5.00	6.00	6.00	7.00	5.00	6.00	5.00	7.00	6.00	0.00	7.00	6.00	7.00
20	6.50	6.17	6.80	6.50	6.50	5.67	6.83	6.67	5.50	5.83	4.00	6.40	6.20	6.20	1.33
21	6.00	6.00	5.33	5.33	6.00	6.00	6.00	7.33	5.00	6.00	5.67	5.00	6.00	ND	5.00
22	7.00	5.00	7.00	5.00	5.00	5.17	5.50	6.17	5.70	7.00	7.00	7.00	ND	ND	ND
23	6.50	6.67	7.00	5.50	5.67	5.50	6.67	6.00	5.00	5.67	3.50	5.00	6.50	6.00	3.00
24	6.50	6.33	6.20	5.50	5.67	5.67	5.83	5.83	5.50	5.67	4.25	5.00	6.25	5.67	3.33
25	7.50	8.00	7.00	6.50	7.00	8.00	7.00	7.33	6.33	6.33	6.33	8.00	6.00	5.33	0.00
26	7.50	5.50	6.00	7.67	5.67	4.50	6.83	7.67	4.67	7.50	4.00	7.20	6.00	6.00	3.00
27	6.67	6.33	7.00	6.83	6.50	5.67	6.83	6.67	5.50	5.83	4.00	6.40	6.20	6.20	1.33
28	7.33	6.67	6.75	6.00	5.67	6.00	6.25	5.67	4.75	5.20	2.80	3.50	6.33	6.50	0.00
29	7.00	7.00	7.00	7.00	8.00	8.00	7.00	7.00	7.00	7.00	7.00	7.00	5.67	7.00	0.00
30	7.33	6.67	8.67	7.67	8.00	8.00	8.33	6.67	2.00	4.00	0.00	4.50	6.33	7.67	0.00
31	8.00	5.50	7.00	7.00	7,00	7,00	8,00	8,00	8,00	7,00	7,00	9,00	7,00	7,00	6,50
32	7.00	6.00	5.83	7.00	6.00	5.50	6.83	5.83	5.17	7.33	5.00	5.00	5.43	5.50	2.00
33	6.00	6.00	5.33	5.33	7.00	6.00	7.33	7.33	6.00	6.00	5.67	5.00	6.00	ND	0.00
34	7.50	6.75	7.75	6.50	5.25	6.75	6.50	7.00	4.50	6.50	2.33	6.00	7.00	7.00	6.67
35	7.00	7.00	7.00	8.67	7.00	7.00	7.00	7.54	7.00	7.00	7.00	7.00	5.67	7.00	7.00

36	6.83	6.17	7.20	6.83	6.50	5.67	6.83	6.67	6.00	5.83	5.00	6.40	6.00	6.20	0.00

ND: Not determined, Cl: Color, Texture: TEXT, Brian: Brightness, IO: Odor intensity, AA: Appreciation of aroma, IGr: Fatt taste intensity, I Sel : salt taste intensity, I Ail: garlic taste intensity, I Cum: Cumin taste intensity, I Carv: Caraway taste intensity, I Cor: coriander taste intensity, Sav I: pleasant of flavor, Sav A: Pleasant after taste, Ran: Rancidity

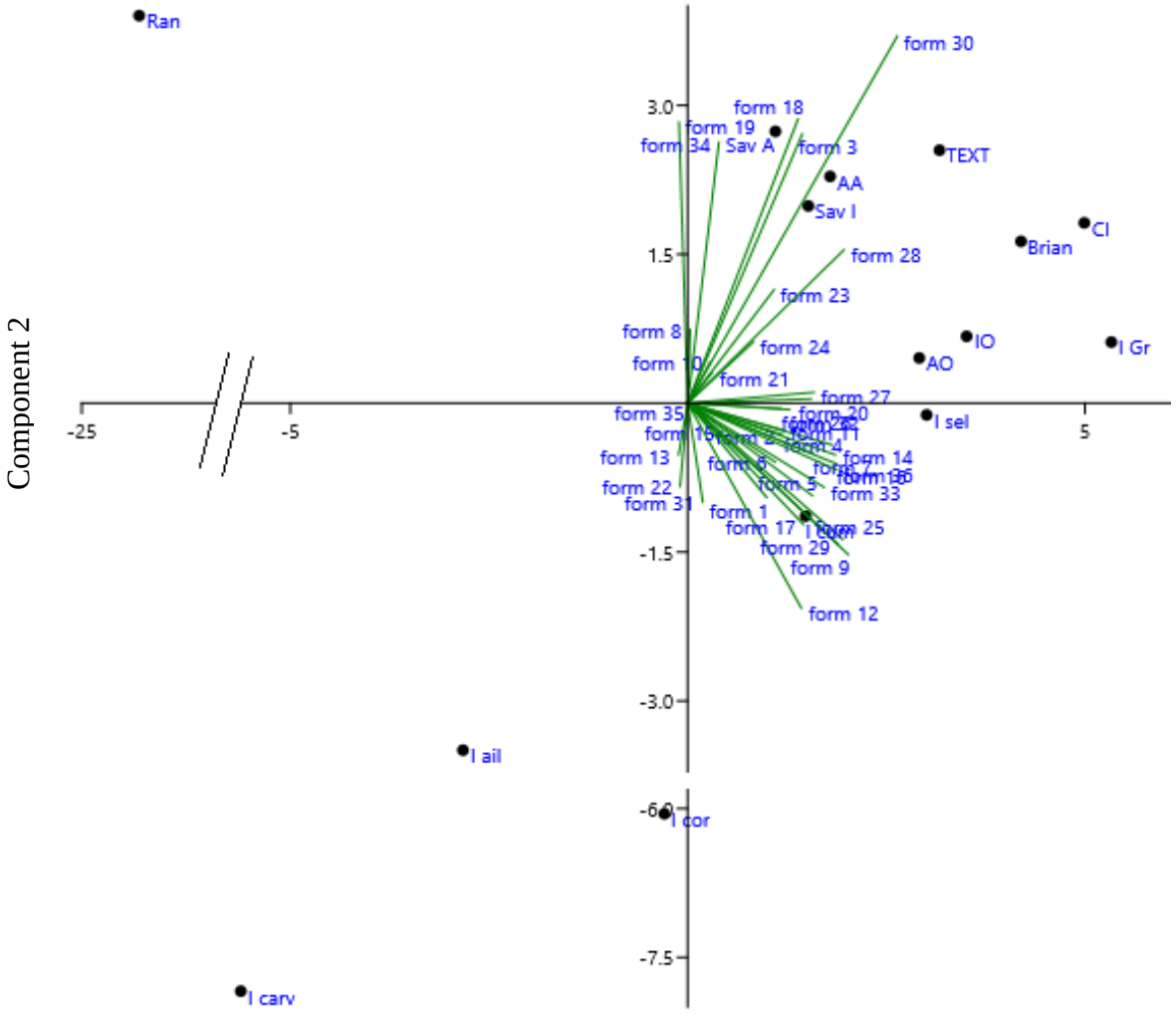

Figure 1. PCA of sensory quality of meat products (*Khlia*)

Cl: Color, Texture: TEXT, Brian: Brightness, IO: Odor intensity, AA: Appreciation of aroma, IGr: Fatt taste intensity, I Sel: salt taste intensity, I Aïl: garlic taste intensity, I Cum: Cumin taste intensity, I Carv: Caraway taste intensity, I Cor: coriander taste intensity, Sav I: pleasant of flavor, Sav A: Pleasant after taste, Ran: Rancidity. Form: the 36 formulations of experimental design.

$$Y_{Sav\ A} = 6.05 + 0.11X_1 - 0.265X_2 + 0.04X_3 - 0.34X_4 + 0.27X_5$$

$Y_{Sav\ A}$ represents the pleasant after taste of meat products, which also important to the flavor appeal, related to the concentration of which has the most important effect; the mathematical effect could be adapted to find the relationship between flavor and some variables. The after tasting pleasant is attributes positively to several factors such as cumin and garlic concentrations and negatively to caraway. Normally as reported by [18] the aftertaste is related to some volatile components. The volatile compounds could be from spices or lipid peroxidation [19].

3.4. Principal component analysis (PCA) of tasting analysis

The dimensional analysis (PCA) carried out on the parameters studied is summarized in the following Table 10. *Khlia* is manufactured by rubbing a mixture of spices and curing agent (salt) which distributes follows experiment design results 36 combinations. Analysis shows that mixtures 3, 18, 19, 30, and 34 are grouped and contribute positively to component 2 (PC2). Almost all formulations are grouped in pool 2 and contribute negatively to component 1 (PC1) and positively to component 2 (PC2). The first component axis (PC1) explained 64.99 % of the total variation and the second one (PC2) explained 13.63% of the variance. These distributions show that the levels of variables in the mixtures can group the *Khlia* mixtures and characterize them according to their contents and their sensory quality. The pleasantness of aroma and flavor intensity contribute to the positive part of component 1 and come into association with the mixtures containing a high quantity of garlic. These results are in accordance with [20] who worked on another matrix (PCA of sensory attributes of artisanal table olives). Fig. 1 shows that PC1 and PC2 allow a clear separation into three groups. These distributions show that the factor concentrations can group the mixtures and characterize them according to their contents and organoleptic quality. The first group included *Khlia* mixtures 3, 18, 28, 23, 24 due to its high percentage of garlic and low concentration of salt, which affect the Pleasantness of aroma and flavor intensity. This group is correlated and contributed positively to PC1.

These results are in accordance with [20] who worked on another matrix (PCA of sensory attributes of artisanal table olives). PCA is done to better understand the effective extraction of high content of phenolic compounds and flavonoids as [21] reported that a strong correlation between ant oxidative activities and phenolic compounds was found. Therefore, phenolic compounds include flavonoids are probably the major contributor to their antioxidant capacity. The sensorial differences among the mixtures prepared by mixture experimental design since most attributes' mixtures are close to PC1 Accept (Ran, I Aïl, I caraway, I cord1). Some sensory characteristics (appreciation of aroma pleasant flavor, Pleasant after taste) are mainly and positively correlated with the mixtures characterized by high concentrations of garlic and low levels of salt. [22] Reported the sensory attributes of dry-meat beef including what is studied in PCA analysis. The data showed significant effect of variables concentrations on sensory attributes after one-year (2020-2021) of preservation. To control the variables effect on the organoleptic quality and preservation, two statistical tools experimental design and ACP were used. *Kaddid* as the most important ingredient for the traditional Moroccan meat product (*Khlia*) formulation was studied in the previous work [23, 24].

Kaddid is dry meat preserved by salting and drying, the salt level is more important for the good preservation against microbial growth but in this study, the focus was to find the best combinations that could preserve the dry meat products even with less salt. [25] confirm the effect of spicing on the water activity, drying behavior and microbial flora of cured meat products (*Kaddid*). Also [24] report the salting step as one of the important processes that make some changes in meat protein characteristics which could generate new aromatic compounds. [26] report the levels of *Khlia* flavor intensity and acidity which related in this study in based on ACP and experimental design with the high level of garlic and less salt concentration. [27] noted the shelf stability during 30 day and the preliminary step of formulation. The sensory attributes of cured meat products (e.g., flavor, aroma, odor) are related to the volatiles compounds that acquired by either during marinade with salt and spices or during drying which related to lipid peroxidation that give desirable flavor to cured meat products [3, 28]. The improvement of sensory quality, nutritional value an even the preservation of meat products could be achieved by the addition of spices and bioactive compounds [29]. [30] reported the meat substitutes and in this work, instead of using meat substitutes, we try to improve meat products to benefit of the entire nutrient without salt or harmful additives that could compromise the quality of this important element.

4. Conclusions

This study presents results about the formulation of 36 mixtures of *Kaddid* (Salted, marinated and dried meat products), which were used for the formulation of 36 cooked meat products (*Khlia*) by experimental design. The sensory evaluation of 36 formulations was done after preservation for one-year and tasters of 60 students and professors members of the staff of physiopathology and nutrition, faculty of medicine, university of sidi Mohamed Abdellah. The sensory analysis was carried out in one day. In this work, we were able to evaluate the effect of spices and salt on the preservation and saving flavor after one year, using mixtures experimental Plakett-Burman design. Results showed that the experimental Plakett-Burman design was a good method to select or screening the factors affecting the sensory and flavor preservation. After the statistical validation of the model obtained, we moved on to the analysis of factors effects. Thus, this model made it possible; to know which factor (salt, garlic, coriander, cumin, caraway) concentrations were all factors, which influence taste and sensory quality of *Khlia*. According to the tasters, all factors had significant effects on taste but the high effect of salts, particularly on rancidity, was linked to lipid oxidation and fungal spoilage. To complete this study, an optimization study must be carried out. It will consist of seeking the optimal operating conditions likely to guarantee better preservation by reducing the microbial load by working on a response surface.

References

[1] M. Gagaoua, H.R. Boudechicha. (2018). Ethnic meat products of the North African and Mediterranean countries: An overview. Journal of Ethnic Foods, 5, 83-98.

[2] M. Flores. (2018). Understanding the implications of current health trends on the aroma of wet and dry cured meat products. Meat Science, 144, 53-61.

[3] H. Yao, Y.L. Xu, W. Liu, Y. Lu, J.H. Gan, Y. Liu, C.H. Xu. (2022). Taste compounds generation and variation of broth in pork meat braised processing by chemical analysis and an electronic tongue system. Journal of Food Biochemistry, 46, 13766.

[4] L. Bennani, Y. Zenati, M. Faid, M. Ettayebi. (1995). Physico-chemical and microbiological characteristics of a dried salted meat product (Kaddid) in Morocco. Zeitschrift für Lebensmittel-Untersuchung und Forschung, 201, 528-532.

[5] P.D. Chiang, C.T. Yen, J.L. Mau. (2007). Non-volatile taste components of various broth cubes. Food Chemistry, 101, 932-937.

[6] N. Benkerroum. (2013). Traditional fermented foods of North African countries: technology and food safety challenges with regard to microbiological risks. Comprehensive Reviews in Food Science and Food Safety, 12, 54-89.

[7] M. Fadil, A. Farah, B. Ihssane, T. Haloui, S. Rachiq. (2015). Optimisation des paramètres influençant l'hydrodistillation de Rosmarinus officinalis L. par la méthodologie de surface de réponse Optimization of parameters influencing the hydrodistillation of Rosmarinus officinalis L. by response surface methodology. Journal of Materials and Environmental Science, 6, 2346-2357.

[8] E.D. Othón-Díaz, J.O. Fimbres-García, M. Flores-Sauceda, B.A. Silva-Espinoza, L.X. López-Martínez, A.T. Bernal-Mercado, J.F. Ayala-Zavala. (2023). Antioxidants in Oak (Quercus sp.): Potential Application to Reduce Oxidative Rancidity in Foods. Antioxidants, 12, 861.

[9] A. Honrado, A. Aínsa, P.L. Marquina, J.A. Beltrán, J.B. Calanche. (2022). Low-fat fresh sausage from rabbit meat: An alternative to traditional rabbit consumption. Meat Science, 194, 108973.

[10] I. Benet, M.D. Guàrdia, C. Ibañez, J. Solà, J. Arnau, E. Roura. (2016). Low intramuscular fat (but high in PUFA) content in cooked cured pork ham decreased Maillard reaction volatiles and pleasing aroma attributes. Food Chemistry, 196, 76-82.

[11] C. Diez-Simon, R. Mumm, R.D. Hall. (2019). Mass spectrometry-based metabolomics of volatiles as a new tool for understanding aroma and flavour chemistry in processed food products. Metabolomics, 15, 1-20.

[12] L. Sun, J. Chen, M. Li, Y. Liu, G. Zhao. (2014). Effect of star anise (I llicium verum) on the volatile compounds of Stewed chicken, Journal of Food Process Engineering, 37, 131-145.

[13] R. Ramírez, R. Cava. (2007). Volatile profiles of dry-cured meat products from three different Iberian X Duroc genotypes, Journal of Agricultural and Food Chemistry. 55, 1923-1931.

[14] M.I. Cambero, G.D. García de Fernando, M.D. Romero de Ávila, V. Remiro, L. Capelo, J. Segura. (2023). Freeze-Dried Cooked Chickpeas: Considering a Suitable Alternative to Prepare Tasty Reconstituted Dishes. Foods, 12, 2339.

[15] C.R. Kerth, R.K. Miller. (2015). Beef flavor: A review from chemistry to consumer, Journal of the Science of Food and Agriculture, 95, 2783-2798.

[16] L. Zhang, Z. Hao, C. Zhao, Y. Zhang, J. Li, B. Sun, Y. Tang, M. Yao. (2021). Taste compounds, affecting factors, and methods used to evaluate chicken soup: A review. Food Science & Nutrition, 9, 5833-5853.

[17] M. Hu, S. Wang, Q. Liu, R. Cao, Y. Xue. (2021). Flavor profile of dried shrimp at different processing stages, Lwt- Food Science and Technology, 146, 111403.

[18] R.Q. He, P. Wan, J. Liu, D.W. Chen. (2020). Characterisation of aroma-active compounds in Guilin Huaqiao white sufu and their influence on umami aftertaste and palatability of umami solution, Food chemistry, 321, 126739.

[19] C.R. Calkins, J.M. Hodgen. (2007). A fresh look at meat flavor, Meat science, 77 (1) 63-80.

[20] S. Dahmani, F. Errachidi, A. Bour, W. Berrada, L. El Ghadraoui, R. Chabir. (2018). Nutritional Composition and Sensory Profile of Moroccan Orange Juices, research journal of pharmaceutical biological and chemical sciences, 9, 255-264.

[21] P. Thiviya, A. Gamage, D. Piumali, O. Merah, T. Madhujith. (2021). Apiaceae as an Important Source of Antioxidants and Their Applications. Cosmetics, 8 111.

[22] S. Liu, Y. Zhang, P.W. Harlina, G. Zhou, Z. Peng. (2020). Sensory characteristics of low sodium dry-cured beef and their relation to odor intensity and electronic nose signals, International Journal of Food Properties, 23, 116-126.

[23] L. Bennani, M. Faid, A. Bouseta. (2000). Experimental manufacturing of kaddid, a salted dried meat product: control of the microorganisms, European Food Research and Technology, 211, 153-157.

[24] R. Benlacheheb, S. Becila, M.A. Sentandreu, K. Hafid, H.-R. Boudechicha, A. Boudjellal. (2019). El Gueddid a traditional Algerian dried salted meat: Physicochemical, microbiological characteristics and proteolysis intensity during its manufacturing process and ripening, Food Science and Technology International, 2, 347-355.

[25] M. Chabbouh, A. Sahli, S. Bellagha. (2013). Does the spicing step affect the quality and drying behaviour of traditional kaddid, a Tunisian cured meat?, Journal of the Science of Food and Agriculture, 93, 3634-3641.

[26] H.R. Boudechicha, M. Gagaoua, K. Hafid, S. Becila, A. Boudjellal, T. Astruc. (2015). Khliaa Ezir, a traditional cured meat product of Algeria: preparation and characterization, Proceedings of the 61th International Congress of meat science and meat technology, 02743708

[27] H.R. Boudechicha, I. Nasri, Z. Bennaceur, M.

Sellama, K. Hafid, A. Boudjellal, M. Gagaoua. (2017). Microbiological changes during the preparation steps of Khliaa Ezir: a traditional cured meat product of Algeria, Integrative Food, Nutrition and Metabolism, 4, 1-5.

[28] L.M. Nollet, F. Toldrá. (2008). Handbook of processed meats and poultry analysis, CRC Press.

[29] G. Squeo, D. De Angelis, R. Leardi, C. Summo, F. Caponio. (2021). Background, applications and issues of the experimental designs for mixture in the food sector, Foods, 10, 1128.

[30] S. Smetana, A. Profeta, R. Voigt, C. Kircher & V. Heinz. (2021). Meat substitution in burgers: Nutritional scoring, sensorial testing, and life cycle assessment. Future Foods 4, 100042.