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Volatile organic compounds and consumer preference for meat from suckling goat kids raised with natural or replacers milk

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ABSTRACT

Most of European Union goats are slaughtered with carcase weights between 5 kg and 11 kg. Some farmers rear kids with milk replacers to produce cheese with the dams' milk. The aim of this experiment was to study the volatile compounds (VOCs) of meat of suckling light kids reared with natural milk or milk replacers and to study the influence of consumers' psychographic characteristics on the sensory preference for meat. Gas chromatography-mass spectrometry was performed to identify the VOCs and consumers evaluated the flavour, juiciness and overall acceptability. Thirty-five VOCs were detected and 44.3%, 25.1%, 6.9% and 2.3%, were aldehydes, hydrocarbons, ketones and alcohols, respectively. The influence of the rearing system on VOCs clearly depended on the breed. The use of milk replacers did not affect the percentage of linear aldehydes compared to the use of natural milk. However, the major aldehyde, hexanal (34.8%), was related to the use of natural milk and correlated positively with both the flavour ($r = 0.21$) and overall acceptability ($r = 0.24$). On the other hand, hydrocarbons such as hexane were related to MR, and 2-methyl-pentane and 3-methyl pentane were correlated with the acceptability of flavour ($r = -0.22$ and -0.25, respectively) and with the overall acceptability ($r = -0.21$ and -0.24). The 2-penthyl furan and 2-ethyl-1-hexanol were correlated with the overall acceptability ($r = -0.22$ and -0.22, respectively). Therefore, the acceptability of meat from suckling kids fed natural milk was greater for older consumers and people with a moderate consumption of meat.

HIGHLIGHTS

- Goat farmers remove the kids from their dams at a very young age and rear them with milk replacers, but this practice may alter the flavour of meat.
- The major aldehyde, hexanal, was related to the use of natural milk and correlated positively with the flavour and overall acceptability.
- Acceptability of meat from suckling kids fed natural milk was greater for older consumers and people with a moderate consumption of meat.

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Introduction

Spain has one of the largest goat populations in the European community, producing 20% of the milk goats and 10.9% of the kid meat in the European Union (MAPAMA 2016). In addition, suckling kid sales are 20% of the final income per goat of the dairy farm (Castel et al. 2012). Eighty per cent of this kid meat comes from the light suckling kid category (*cabrito*) (MAPAMA 2016). These light suckling kids have a live weight of 10–11 kg and carcase weight of 5–7 kg, and are perceived by consumers to be high-quality meat (Marichal et al. 2003). In fact, 88% of European Union goats are raised and slaughtered as kids with carcase weights between 5 kg and 11 kg (Shrestha and Fahmy 2007). When kid goats are reared with their dams, the availability of milk for cheese production decreases. Therefore, some goat farmers remove the kids from their dams at a very young age and rear them with

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milk replacers, as is standard in intensive dairy cow production. Milk replacers specially formulated for kids can result in good daily weight gain. However, some farmers are disinclined to use the milk replacers because this type of rearing involves greater labour costs, even though the total costs are equal to or higher than those for the natural suckling systems (Delgado-Pertíñez et al. 2009). Additionally, some farmers choose to feed their kids with natural goat milk, believing that this increases meat quality (Bañón et al. 2006). However, leg chops of kids reared with milk replacers were preferred by consumers according to their visual appraisal. Moreover, the purchase intention of these chops was also greater than that for kids reared with natural milk (Ripoll et al. 2018). Selecting a rearing system of very light suckling kids is not a trivial question. Meat with high pH appears with more frequency when very light suckling kids are reared with milk replacers affecting to muscle colour (Ripoll et al. 2019); and colour is one of the most important quality attributes to choose meat at the purchase time (Bernués et al. 2012).

Factors that influence the meat flavour can be grouped into three levels: animal (breed and feeding type), meat (pre-slaughter handling and ageing) and cooking (Drumm and Spanier 1991; Mottram 1998; Aaslyng and Meinert 2017). The most important factors of cooking are the temperature and cooking time, because they generate Maillard reactions and lipid degradation (Aaslyng and Meinert 2017). In addition, we must consider a last step, the consumer. The perception of meat flavour are determined by consumers' individual preferences (Calkins and Hodgen 2007) since small changes in sensory ratings for flavour can greatly influence the overall acceptability of the meat (Platter et al. 2003).

Raw meat is weakly flavoured, but the thermal treatment of lean meat provides a non-species-specific meaty flavour, whereas warming up meat containing fat develops species-specific flavour. Meaty flavour is composed of thousands of volatile compounds including hydrocarbons, aldehydes, ketones, alcohols, furans, thriphenes, pyrroles, pyridines, pyrazines, oxazoles, thiazoles, sulphurous compounds, and many others, but only a minor group are responsible for the characteristic odour and flavour of meat (Shahidi 1998). The major volatile compounds are produced by the thermal degradation of fat and the oxidation of fatty acids, which is primarily responsible for the development of flavour. However, the meat of suckling kids is very lean and it is expected to have a low odour intensity. Slaughter weight is related to the intensity of kid-specific odour and milk odour of kids (Ripoll et al. 2012). There is scarce information on the use of milk replacers on the flavour of meat from suckling light kids such as *cabrito*; however, the pre-harvest animal environment and diet are decisive factors in the desirability of meat (Calkins and Hodgen 2007). In fact, some authors detected an influence of the milk on meat quality of suckling light lambs (Wilches et al. 2011; Morán et al. 2014).

The aim of this study was to characterise the different volatile compounds found in the cooked meat of suckling light kids reared with natural milk or milk replacers and the influence of consumers' psychographic characteristics on the sensory preference for meat from these rearing systems.

Material and methods

Animals and sampling

All procedures were conducted according to the guidelines of Directive 2010/63/EU on the protection of animals used for experimental and other scientific purposes (EU 2010).

Suckling male kids of eight goat breeds (Florida: FL; Cabra del Guadarrama: GU; Majorera: MA; Palmera: PL; Payoya: PY; Retinta: RE; Tinerfeña: TI; Verata: VE) were evenly reared at two (FL, MA, PL, PY and TI) or three farms (GU, RE and VE) per breed in their respective local areas. Each farm-reared approximately a half of kids into each rearing system. Animals were selected to be as unrelated as possible to ensure that the full range of genetic diversity was present within breeds in the study. Animals were all born from single parturition and were raised with milk replacers (MR) or natural milk from their dams (NM). Kids of the MR rearing system were fed colostrum for the first 2 days and then had free access to the milk replacer for 24 h a day, which was suckled from a teat connected to a unit for feeding a liquid diet. Commercial milk replacers were reconstituted at 17% (w/v) and given warm (40 °C). The main ingredients were skimmed milk (60%) and whey. The chemical composition of milk replacers was: Total fat 25% ± 0.6, crude protein 24% ± 0.5, crude cellulose 0.1% ± 0.0, ash 7% ± 0.6, Ca 0.8% ± 0.1, Na 0.5% ± 0.2, P 0.7% ± 0.0, Fe 36 mg/kg ± 4.0, Cu 3 mg/kg ± 1.7, Zn 52 mg/kg ± 18.8, Mn 42 mg/kg ± 14.4, I 0.22 mg/kg ± 0.06, Se 0.1 mg/kg ± 0.06 and butylated hydroxytoluene 65 ppm ± 30. The chemical composition of natural milk was: Total fat 5.00% ± 0.08, crude protein 4.02% ± 0.6, and lactose 4.14% ± 0.02. Kids of the NM rearing system suckled directly from dams with no additional feedstuff. At

Table 1. Volatile compounds (aldehydes) of kids reared with milk replacer (MR) or natural milk from their dams (NM).

B	RS	*n*	Pentanal	Hexanal	Heptanal	Octanal	Nonanal	2-Methyl propanal	2-Methyl butanal	3-Methyl butanal	2-Ethyl Hexanal
FL	MR	15	1.460^{bc}	45.870^{bcd}	1.580^{bcde}	0.890^{cde}	3.740^{ef}	n.d.	0.120^{cd}	0.100^{b}	0.150^{ab}
	NM	15	1.910^{b}	48.430^{abc}	2.450^{ab}	1.320^{abcd}	5.090^{cdef}	n.d.	0.140^{cd}	0.160^{b}	0.190^{ab}
GU	MR	15	0.830^{cdef}	35.340^{cde}	1.050^{cdef}	0.840^{cde}	4.000^{def}	n.d.	n.d.	n.d.	n.d.
	NM	16	0.990^{cd}	46.360^{bcd}	1.120^{cdef}	1.430^{abc}	10.530^{a}	n.d.	0.110^{cd}	0.130^{b}	n.d.
MA	MR	16	0.280^{f}	23.260^{efg}	0.670^{ef}	0.830^{cde}	3.190^{f}	n.d.	n.d.	n.d.	0.070^{ab}
	NM	16	0.610^{def}	41.850^{bcd}	2.170^{abc}	1.660^{ab}	6.680^{bcd}	n.d.	n.d.	n.d.	0.030^{b}
PL	MR	15	0.320^{ef}	29.780^{def}	0.950^{def}	1.610^{ab}	7.420^{bc}	n.d.	n.d.	n.d.	0.110^{ab}
	NM	16	0.400^{def}	30.360^{def}	1.850^{bcd}	1.410^{ac}	6.230^{bcde}	n.d.	n.d.	n.d.	0.120^{ab}
PY	MR	16	0.960^{cde}	56.590^{ab}	1.570^{bcde}	1.070^{bcde}	5.380^{cdef}	n.d.	0.240^{bc}	0.880^{a}	0.130^{ab}
	NM	14	2.090^{b}	63.040^{a}	2.610^{ab}	1.790^{a}	6.640^{bcd}	n.d.	0.020^{d}	0.070^{b}	0.020^{b}
RE	MR	15	n.d.	2.900^{h}	0.390^{f}	0.450^{e}	2.970^{f}	n.d.	0.410^{a}	0.200^{b}	0.260^{a}
	NM	15	0.220^{b}	9.130^{gh}	0.670^{ef}	0.680^{de}	3.090^{f}	0.090^{a}	0.320^{ab}	0.270^{b}	0.210^{ab}
TI	MR	16	0.230^{b}	16.990^{fgh}	1.780^{bcde}	1.050^{bcde}	4.470^{def}	n.d.	n.d.	n.d.	0.060^{b}
	NM	16	0.260^{b}	24.490^{efg}	1.270^{cdef}	1.490^{abc}	6.650^{bcd}	n.d.	n.d.	n.d.	0.120^{ab}
VE	MR	15	0.700^{def}	30.660^{def}	1.100^{cdef}	1.000^{bcde}	3.910^{def}	0.070^{b}	0.460^{a}	0.690^{a}	0.200^{ab}
	NM	15	3.270^{a}	54.150^{ab}	3.040^{a}	1.880^{a}	8.710^{ab}	n.d.	0.320^{ab}	0.240^{a}	0.110^{ab}
	s.e.		0.1290	3.2850	0.2270	0.1340	0.5650	0.0060	0.0290	0.0550	0.0380
	B		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	RS		0.0001	0.0001	0.0001	0.0001	0.0001	0.4950	0.0050	0.0001	0.2700
	B*RS		0.0001	0.0070	0.0001	0.0010	0.0001	0.0001	0.0001	0.0001	0.2350

B: Breed; RS: Rearing system; s.e.: standard error; FL: Florida; GU: del Guadarrama; MA: Majorera; PL: Palmera; PY: Payoya; RE: Retinta; TI: Tinerfeña; VE: Verata; n.d.: No detected.
The volatile compounds are expressed as percentage of total detected volatile compounds.
Different superscripts indicate significant differences within the same column ($p < .05$).

night, they were housed with their dams in a stable. Kids from both rearing systems had free access to water.

The numbers of kids used are shown in Table 1. The 246 kids were slaughtered at a body weight of 8.47 kg ± 0.077 kg. Standard commercial procedures according to the European normative of protection of animals at the time of killing (E.U. 2009) were followed. Head-only electrical stunning was applied (1.00 A) to the kids, which were then exsanguinated and dressed with a hot carcase weight of 4.97 kg ± 0.061 kg. Carcases were hung by the Achilles tendon and chilled for 24 h at 4 °C in total darkness. Then, carcases were split into two halves, and the muscle *longissimus lumborum* (LL) (Jambrenghi et al. 2007; Hukerdi et al. 2019) of the left half carcase was extracted, vacuum-packed and aged for 3 days at 4 °C. Then, a 2-cm long portion of the LL was cut, vacuum-packed and frozen at −80 °C (Sanyo MDF-U5386S, SANYO Electric Co., Ltd., Osaka, Japan) until volatile compounds analysis. The remaining LL was also vacuum-packed and frozen at −20 °C until sensory analysis.

Extraction and analysis of volatile compounds

Gas chromatography-mass spectrometry (GC-MS) was performed to identify the volatile compounds (VOCs) in the meat. Meat samples were thawed and cut to ensure a 2-cm thickness. Then, samples were cooked to a core temperature of 75 °C. Samples were minced, and 1 g was weighed into a 5 mL headspace vial (Hewlett–Packard, Palo Alto, CA, USA) and sealed with a PTFE butyl septum (Perkin-Elmer, Foster City, CA, USA) in an aluminium cap. Volatile compounds were extracted with a solid-phase microextraction (SPME) technique with a 10-mm long, 75-μm thick fibre coated with carboxen/polydimethylsiloxane (Supelco Co., Bellefonte, PA, USA). Prior to the collection of volatiles, the fibre was preconditioned at 300 °C for 1 h in the GC injection port. The SPME fibre was inserted into the headspace vial through the septum, and exposed to the headspace for 55 min at 40 °C in a water bath with stirring. GC-MS analyses of VOCs were performed using a Hewlett–Packard 5890 S II gas chromatograph coupled with a Hewlett–Packard 5971A ion-trap mass spectrometer. A 5% phenyl 95% dimethyl polysiloxane column (50 m × 0.32 mm ID, 1.05-μm film thickness; Hewlett–Packard) was used for the separation of the VOCs. Helium was used as the carrier gas. The injection port was in a splitless mode. The SPME fibre was kept in the injection port at 250 °C during the chromatographic run. The temperature programme began in an isothermal mode for 5 min at 35 °C and ramped to 150 °C at 4 °C min^{-1}, followed by 250 °C at 20 °C min^{-1}. The GC-MS transfer line temperature was 280 °C. The mass spectrometer was operated in the electron impact mode, with an electron energy of 70 eV, a multiplier voltage of 1756 V and a rate of 1 scan s^{-1} over a range of m z^{-1} 20–365 for data collection. To calculate the Kovats indexes for the different compounds, n-alkanes (Sigma R-8769) were run under the same conditions. The VOCs of cooked meat were identified by comparison of their mass spectra with data in the NIST database and the calculated Kovats indexes. Quantification was based on either the total or single ion chromatogram on an arbitrary scale.

Consumer sensory test

Participation of the naive consumers in the experiment was voluntary and anonymous. Personal data including identification and electronic mail were not required, and there was no economic compensation. Participants were informed clearly about the aim of the study and gave implicit consent to use the supplied information according to European regulations (U.E. 2010). Vegan people did not participate in the study. Sensory analysis was performed with a home test (Dransfield et al. 2000). Each of the 114 consumers was provided with two vacuum-packed and frozen samples of meat from each rearing system of the same breed. Home tests are widely used to acquire information about the product in a realistic situation (Dransfield et al. 2000; Lunde et al. 2010; Aaslyng et al. 2016), and two samples were recommended for the study (Santa Cruz et al. 2005). A sheet with some questions and the instructions were provided with the meat (Annexe A). The meat was to be grilled without condiments such as salt or spices. Home test do not ensure a controlled environment of cooking but scores of the both samples of each consumer are compared in the same conditions. The consumers evaluated the flavour acceptability, juiciness acceptability and overall acceptability of the samples on a scale from 1 (dislike extremely) to 10 (like extremely). Consumers were asked about their age, gender, level of preference for meat, frequency of consumption of meat and if they had previously tasted kid.

Statistical analysis

Statistical analyses were performed with the XLSTAT statistical package v.3.05 (Addinsoft, USA). The percentage of the total area detected for each volatile compound was calculated. Then, VOCs were subjected to an analysis of variance with the breed and rearing system as fixed effects. Flavour acceptability, juiciness acceptability and overall acceptability were mean-centered to reduce the dependence on magnitude and the different use of scale of consumer, and also on differences on cooking between consumers. Hence, the scores of consumers were expressed as a deviation from their own mean, subtracting each score to the average score of each consumer (Ripoll et al. 2014). Flavour acceptability, juiciness acceptability and overall acceptability were studied with an analysis of variance with the rearing system, age, gender, level of preference for meat, frequency of consumption of kid meat and previous consumption of kid meat as fixed effects. The least square means were estimated, and differences were tested with a level of significance at 0.05. The Pearson correlations between volatile compounds and the consumer sensory test were calculated with the residuals of each observation. The dependence between the age and gender of the consumer was studied using the x^2 test.

Results

Volatile compounds

A total of 35 VOCs were identified and quantified. The identified VOCs included 9 aldehydes, 8 hydrocarbons, 4 ketones, 4 alcohols and 6 others such as pyrazines, furans and ethers (Tables 1, 2, 3 and 4, respectively). The remaining four detected VOCs were not identified. The mean percentage of the total area for each group of VOCs was 44.3%, 25.1%, 6.9%, 2.3%, 21.0% and 0.35% for aldehydes, hydrocarbons, ketones, alcohols, others and unknowns, respectively. Hexanal was the major VOC, with 34.8% of the total area. Moreover, hexanal showed the greatest coefficient of variation (CV = 168%). The main VOC were hexane and ethyl acetate with 21.3% and 16.4% of the total area, respectively. The CV of both VOCs was also greater than 100%. The interaction between the breed and the rearing system affected 31 VOCs ($p < .05$), while 2-ethyl hexanal, toluene and carbon disulphide were only affected by breed ($p < .001$). 2.5-dimethyl pyrazine was affected by breed and rearing system ($p < .05$).

In general, the rearing system did not affect the percentage of linear aldehydes from 5 to 9 carbons ($p > .05$) in some breeds (Table 1). However, the use of milk replacers decreased the percentage of these VOCs in other breeds. Verata kids fed NM had the highest values of linear aldehydes from 5 to 9 carbons ($p < .05$). Payoya kids fed NM also had high values for hexanal, heptanal and octanal. Conversely, Retinta kids fed MR had the lowest values for aldehydes from 5 to 9 carbons ($p < .05$). Majorera kids fed MR also had low values for pentanal and nonanal. Retinta kids fed NM had similarly low values for nonanal ($p > .05$). In general, Majorera and Verata kids fed NM had higher percentages of linear aldehydes ($p < .05$) than those fed MR. Regarding the minority aldehydes, 2-ethyl-hexanal was found in almost every breed except Guadarrama. The other minority aldehydes were not detected in

Table 2. Volatile compounds (aliphatic and aromatic hydrocarbons) of kids reared with milk replacer (MR) or natural milk from their dams (NM).

B	RS	2-Methyl pentane	3-Methyl pentane	Hexane	Heptane	Toluene	p-Xylene	o,m-Xylene	Limonene
FL	MR	1.820^{b}	n.d.	20.000^{abcd}	0.120^{bcd}	0.090^{b}	n.d.	0.190^{b}	0.320^{bc}
	NM	1.630^{b}	n.d.	14.850^{bcde}	0.060^{cd}	0.160^{b}	n.d.	0.330^{b}	0.330^{bc}
GU	MR	1.610^{bc}	4.630^{c}	31.550^{a}	n.d.	n.d.	0.320^{a}	0.040^{c}	0.190^{c}
	NM	0.600^{cd}	1.870^{de}	26.450^{ab}	n.d.	n.d.	0.290^{a}	n.d.	n.d.
MA	MR	0.270^{d}	0.500^{ef}	30.690^{ab}	0.320^{bc}	n.d.	n.d.	0.020^{c}	0.460^{bc}
	NM	0.250^{d}	0.300^{ef}	23.980^{abc}	1.030^{a}	n.d.	n.d.	0.060^{c}	0.620^{ab}
PL	MR	0.080^{d}	0.110^{f}	9.400^{cde}	n.d.	n.d.	n.d.	n.d.	0.330^{bc}
	NM	0.200^{d}	0.150^{ef}	19.490^{abcd}	0.020^{d}	n.d.	n.d.	n.d.	0.290^{bc}
PY	MR	0.280^{d}	n.d.	6.150^{de}	0.020^{d}	0.360^{a}	n.d.	2.650^{a}	0.630^{ab}
	NM	0.510^{d}	n.d.	3.040^{e}	0.340^{b}	0.320^{a}	n.d.	0.690^{b}	0.920^{a}
RE	MR	3.870^{a}	7.080^{b}	33.550^{a}	n.d.	n.d.	n.d.	n.d.	0.630^{ab}
	NM	4.310^{a}	10.650^{a}	34.180^{a}	0.020^{d}	n.d.	n.d.	n.d.	0.480^{bc}
TI	MR	0.130^{d}	0.240^{ef}	19.170^{abcd}	n.d.	n.d.	0.160^{b}	n.d.	0.630^{ab}
	NM	0.280^{d}	0.300^{ef}	28.620^{ab}	0.010^{d}	n.d.	n.d.	n.d.	0.350^{bc}
VE	MR	0.870^{bcd}	2.980^{ced}	34.720^{a}	0.040^{d}	n.d.	n.d.	n.d.	0.510^{bc}
	NM	0.850^{bcd}	0.360^{ef}	3.480^{de}	0.190^{bcd}	n.d.	n.d.	n.d.	0.450^{bc}
	s.e.	0.2000	0.3430	3.2320	0.0530	0.0180	0.0270	0.1050	0.0670
	B	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	RS	0.7000	0.1690	0.0170	0.0001	0.7490	0.0920	0.0001	0.3150
	B*RS	0.0250	0.0001	0.0001	0.0001	0.1940	0.0410	0.0001	0.0010

B: Breed; RS: Rearing system; s.e.: standard error; FL: Florida; GU: del Guadarrama; MA: Majorera; PL: Palmera; PY: Payoya; RE: Retinta; TI: Tinerfeña; VE: Verata; n.d.: No detected.
The volatile compounds are expressed as percentage of total detected volatile compounds.
Different superscripts indicate significant differences within the same column ($p < .05$).

Table 3. Volatile compounds (ketones and alcohols) of kids reared with milk replacer (MR) or natural milk from their dams (NM).

B	RS	Acetone	3-Hydroxy-2-butanone	3-Heptanone	2-Methyl-3-octanone	1-Butanol	1-Pentanol	3-Heptanol	2-Ethyl-1-Hexanol
FL	MR	2.620^{bc}	n.d.	3.130^{bc}	2.630^{def}	n.d.	1.530^{cd}	1.540^{b}	0.190^{c}
	NM	2.090^{cd}	n.d.	2.470^{c}	4.380^{bcd}	n.d.	2.190^{bc}	1.380^{b}	0.230^{c}
GU	MR	0.470^{e}	n.d.	n.d.	0.350^{g}	n.d.	1.210^{de}	n.d.	n.d.
	NM	n.d.	n.d.	0.060^{e}	1.890^{efg}	0.670	2.260^{bc}	n.d.	n.d.
MA	MR	0.360^{e}	n.d.	0.010^{e}	2.380d^{efg}	n.d.	n.d.	n.d.	n.d.
	NM	1.120^{de}	n.d.	n.d.	5.750^{ab}	n.d.	n.d.	n.d.	n.d.
PL	MR	0.410^{e}	n.d.	0.020^{e}	2.420^{defg}	n.d.	n.d.	n.d.	n.d.
	NM	0.570^{e}	n.d.	0.020^{e}	2.850^{cde}	n.d.	n.d.	n.d.	n.d.
PY	MR	2.570^{bc}	0.520^{b}	2.900^{bc}	6.210^{ab}	n.d.	3.830^{a}	2.390^{a}	0.100^{c}
	NM	2.670^{bc}	0.040^{c}	2.450^{c}	4.890^{abc}	n.d.	2.520^{b}	1.300^{b}	0.430^{b}
RE	MR	5.060^{a}	1.260^{a}	5.810^{a}	0.530^{fg}	n.d.	0.190^{f}	2.620^{a}	1.000^{a}
	NM	5.500^{a}	n.d.	3.630^{b}	0.960^{efg}	n.d.	0.530^{ef}	2.170^{a}	0.550^{b}
TI	MR	0.380^{e}	n.d.	0.010^{e}	0.710^{fg}	n.d.	n.d.	n.d.	n.d.
	NM	0.390^{e}	n.d.	0.010^{e}	2.270^{defg}	n.d.	n.d.	n.d.	n.d.
VE	MR	3.540^{b}	0.390^{c}	1.420^{d}	5.520^{ab}	n.d.	2.260^{bc}	1.420^{b}	0.250^{c}
	NM	6.050^{a}	n.d.	2.890^{bc}	6.920^{a}	n.d.	2.300^{bc}	2.310^{a}	0.220^{c}
	s.e.	0.2620	0.0690	0.1940	0.4260	0.0290	0.1580	0.1700	0.0330
	B	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	RS	0.0050	0.0001	0.0230	0.0001	0.0001	0.2140	0.0820	0.4010
	B*RS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

B: Breed; RS: Rearing system; s.e.: standard error; FL: Florida; GU: del Guadarrama; MA: Majorera; PL: Palmera; PY: Payoya; RE: Retinta; TI: Tinerfeña; VE: Verata; n.d.: No detected.
The volatile compounds are expressed as percentage of total detected volatile compounds.
Different superscripts indicate significant differences within the same column ($p < .05$).

the three breeds from the Canary Islands (Majorera, Palmera and Tinerfeña). The effect of the rearing system on these aldehydes was different for each breed.

The main hydrocarbons were 2-methyl pentane, 3-methyl pentane and hexane (Table 2). The remaining hydrocarbons were less than 1% of the total VOCs. The 2-methyl pentane percentages were similar between rearing systems within breeds ($p > .05$). For this VOC, Majorera, Palmera, Payoya and Tinerfeña kids had the lowest values ($p < .05$) for 2-methyl pentane, while Retinta kids had the highest value ($p < .05$). Retinta kids fed NM had the highest values of 3-methyl pentane ($p < .05$). This VOC was not detected in Florida and Payoya meat. The presence of heptane was greater ($p < .05$) for kids fed NM than that for those fed MR for most of the breeds. However, heptane was not detected in Guadarrama meat, and Florida meat had similar values ($p > .05$) between rearing systems. Toluene was only detected in Florida and Payoya meat, with no differences

Table 4. Volatile compounds (others) of kids reared with milk replacer (MR) or natural milk from their dams (NM).

B	RS	Diethyl ether	Carbone disulphide	Ethyl acetate	Butyric acid	2,5-dimethyl pyrazine	2-pentyl furan
FL	MR	3.620[b]	0.350[c]	7.150[fgh]	n.d.	0.220[a]	0.320[cd]
	NM	2.770[bcd]	0.140[c]	6.580[gh]	n.d.	0.130[ab]	0.320[cd]
GU	MR	0.390[e]	n.d.	15.700[efg]	1.450[a]	n.d.	0.010[d]
	NM	1.030[cde]	n.d.	3.930[gh]	0.050[b]	n.d.	0.210[d]
MA	MR	0.320[e]	2.230[b]	33.880[bc]	n.d.	n.d.	0.040[d]
	NM	0.810[de]	2.410[b]	10.300[efgh]	n.d.	n.d.	0.140[d]
PL	MR	0.070[e]	2.670[b]	43.250[ab]	n.d.	n.d.	0.800[b]
	NM	1.470[cde]	2.310[b]	31.040[cd]	n.d.	n.d.	0.850[b]
PY	MR	1.90[bcde]	n.d.	2.440[h]	n.d.	n.d.	n.d.
	NM	1.040[cde]	0.130[c]	1.610[h]	n.d.	n.d.	0.160[d]
RE	MR	8.200[a]	1.080[bc]	18.600[ef]	n.d.	0.180[ab]	1.690[a]
	NM	8.310[a]	1.200[bc]	11.390[efgh]	n.d.	0.070[b]	0.900[b]
TI	MR	0.870[cde]	4.290[a]	48.350[a]	n.d.	n.d.	0.210[d]
	NM	6.460[a]	4.540[a]	21.650[de]	n.d.	n.d.	0.360[cd]
VE	MR	2.870[bc]	0.510[c]	2.970[h]	n.d.	n.d.	0.670[bc]
	NM	0.760[de]	0.560[c]	0.080[h]	n.d.	n.d.	0.350[cd]
	s.e.	0.4040	0.3060	2.3020	0.0680	0.0230	0.0750
	B	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	RS	0.0070	0.8970	0.0001	0.0001	0.0360	0.1320
	B*RS	0.0001	0.9790	0.0001	0.0001	0.0670	0.0001

B: Breed; RS: Rearing system; s.e.: standard error; FL: Florida; GU: del Guadarrama; MA: Majorera; PL: Palmera; PY: Payoya; RE: Retinta; TI: Tinerfeña; VE: Verata; n.d.: No detected.
The volatile compounds are expressed as percentage of total detected volatile compounds.
Different superscripts indicate significant differences ($p < .05$).

between rearing systems ($p > .05$). The compound p-xylene was only detected in Guadarrama meat, with no differences between rearing systems ($p > .05$), as well as in Tinerfeña kids fed MR. The compound o,m-xylene was only detected in Florida, Majorera and Payoya meat, but the rearing system affected Payoya meat. The o,m-xylene values for Payoya kids fed MR were almost 4-fold greater than those for Payoya kids fed NM ($p < .05$). Limonene was detected in every group except Guadarrama kids fed NM. Moreover, Guadarrama kids fed MR had the lowest limonene values ($p < .05$). In general, the rearing system had no influence on the VOCs content ($p > .05$), but Majorera kids fed NM had more limonene than did Majorera kids fed MR ($p < .05$).

The detected ketones are shown in Table 3. There was no consistent effect of rearing system on acetone. While Florida, Majorera, Palmera, Payoya, Retinta and Tinerfeña kids had similar values for both rearing systems ($p > .05$), Verata kids fed NM had greater values than did Verata kids fed MR ($p < .05$). On the other hand, Guadarrama kids fed NM had no detectable values, and 0.47% acetone when fed with milk replacers. 3-hidroxy-2-butanone was not detected in most of the breeds, but its concentration was greater for MR rearing than for NM rearing ($p < .05$). The influence of the rearing system on 3-heptanone is not clear. While the 3-heptanone values were greater for NM in Guadarrama and Verata kids ($p < .05$), Retinta and Majorera kids had greater values with MR ($p < .05$). The other breeds had similar percentages with any rearing system. There were no differences between rearing systems ($p > .05$), except Majorera kids that had a greater percentage when reared with NM than MR ($p < .05$).

The detected alcohols are shown in Table 3. These alcohols were not detected in Majorera, Palmera and Tinerfeña meat. The meat of kids fed NM from the Guadarrama and Payoya groups had greater values of 1-butanol and 1-pentanol, but those of the other breeds had no differences between rearing systems. There was no effect of rearing system ($p > .05$) on 3-heptanol and 2-ethyl-1-hexanol for most of the breeds.

Table 4 shows another individual compounds. The lowest values of diethyl ether were detected in the meat of Guadarrama, Majorera and Palmera kids fed with MR ($p < .05$), although there were no differences compared with the values from kids of the same breeds fed NM. Tinerfeña kids fed MR had lower diethyl ether percentages than those of the same breed fed NM ($p < .05$) although Verata kids fed MR had greater values than those of the same breed fed NM ($p < .05$). Carbone disulphide was affected only by breed; Florida and Verata kids had the lowest values, and Tinerfeña kids had the highest ($p < .05$). Butyric acid was detected only in Guadarrama meat, and the kids fed MR had a higher percentage than that of kids fed NM ($p < .05$). The compound 2,5-dimethyl pyrazine was detected in Florida meat without differences among rearing systems ($p > .05$) and in Retinta meat, which had greater values when fed MR versus NM ($p < .05$). The rearing system had no effect on the

2-pentyl furan levels in Florida, Guadarrama, Majorera, Palmera, Tinerfeña and Verata meat ($p > .05$). However, the percentage of this furan was greater in Payoya kids fed NM versus MR. The use of MR increased the percentage of this VOC compared to that in NM ($p < .05$).

Preference of consumers for meat from different rearing systems

The consumer sample was equally distributed by gender ($\chi^2 = 2.24$; $p = .6$) with 46% men. The ages of both men and women were similarly distributed ($\chi^2 = 2.60$; $p = .9$), although the percentage of men older than 55 years was slightly greater than that of women at the same age ($p > .05$). The 12.8% of consumers were younger than 25 year, 33.2% were in the 26 to 40 year group, 31.7% were in the 41 to 55 year group and the 22.3% were older than 55 year. Most of the consumers (72.5%) reported a high preference for meat while 25.9% reported intermediate preference and 1.6% reported low preference. The frequency of consumption of meat was lower than 2 times per week for 13.3%, from 3 to 6 times per week for 76.1% and higher than 6 times per week for the 10.6% of consumers. Finally, the 88% reported previous consumption of kid meat.

When the whole population was considered, there were no differences in the acceptability of flavour ($p = .06$), juiciness ($p = .09$) and overall acceptability ($p = .3$) between rearing systems. Additionally, neither gender nor its interaction with the rearing system were significant ($p > .05$) for the sensory variables. The interaction between the rearing system and age was not significant ($p > .05$) for the acceptability of flavour and overall acceptability, but it was significant ($p = .03$) for the acceptability of juiciness. Consumers younger than 55 years did not find differences between rearing systems, but people older than 55 years preferred the NM (Figure 1(a)).

There were no differences in the acceptability of the meat from kids fed NM and MR according to the level of preference for meat ($p > .1$). Consumers with a moderate consumption of meat (3–6 times per week.) showed a greater overall acceptability of NM ($p = .04$) (Figure 1(b)), while the frequency of meat consumption did not affect the acceptability of flavour ($p = .6$) and juiciness between rearing systems ($p = .6$). Consumers who had previously tasted kid meat showed greater acceptability of juiciness ($p = .048$) and overall acceptability ($p = .002$) for NM than MR (Figure 1(c)).

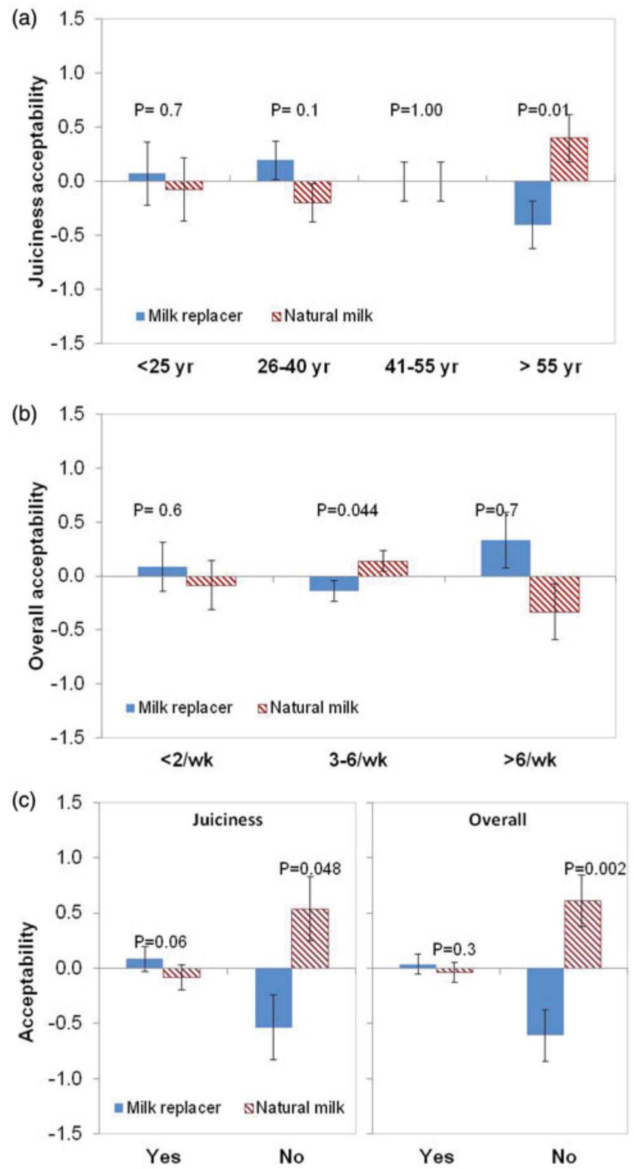

Figure 1. Sensory analysis of meat from kids reared with milk replacers or natural milk. (a) Juiciness acceptability per age of consumer. (b) Overall acceptability per frequency of meat consumption. (c) Juiciness acceptability and overall acceptability of consumers who tasted the kid meat before the test (Yes/No). Rearing system x age of consumer test on juiciness acceptability, $p = .028$). Rearing system x frequency of consumption, $p = .035$. Rearing system x tasted the kid meat before the test on juiciness acceptability, $p = .005$. Rearing system x tasted the kid meat before the test on overall acceptability, $p = .0003$.

Relationship between VOCs and sensory analysis

The three sensory variables were highly correlated ($p < .001$). The overall acceptability was correlated with the acceptability of flavour ($r = 0.80$) and acceptability of juiciness ($r = 0.70$), while the acceptability of juiciness and flavour were less correlated ($r = 0.53$). Therefore, the three variables were placed together as seen in Figure 2. Aldehydes were placed together

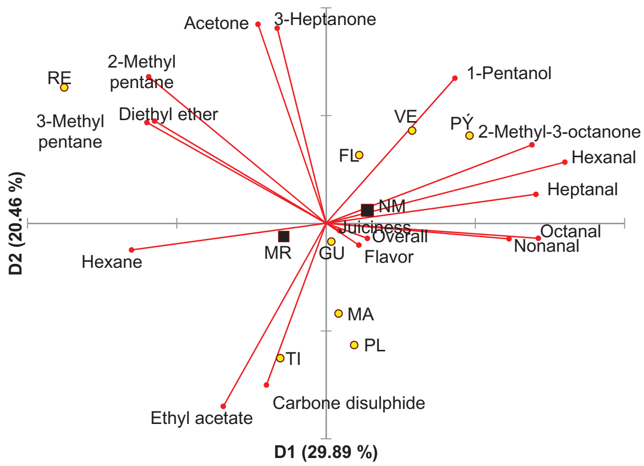

Figure 2. Biplot of the Principal Component Analysis of the volatile compounds of cooked meat of 8 breeds of kids fed natural milk (NM) or milk replacers (MR). FL: Florida; GU: del Guadarrama; MA: Majorera; PL: Palmera; PY: Payoya; RE: Retinta; TI: Tinerfeña; VE: Verata. The volatile compounds are expressed as percentage of total detected volatile compounds.

close to the first axis. Thus, the correlation between hexanal and the acceptability of flavour and overall acceptability was 0.21 and 0.24, respectively ($p < .05$); these aldehydes were related with the NM rearing system. On the other hand, hydrocarbons such as hexane were related to MR, and 2-methyl-pentane and 3-methyl pentane were correlated with the acceptability of flavour ($r = -0.22$ and -0.25, respectively) and with the overall acceptability ($r = -0.21$ and -0.24). The VOC 2-penthyl furan and 2-ethyl-1-hexanol were correlated with the overall acceptability ($r = -0.22$ and -0.22, respectively).

Discussion

Volatile compounds

There are many VOCs detected in the headspace of cooked meat, and most of them are generated by Strecker degradation of amino acids as a part of the Maillard reaction and lipid oxidation (Calkins and Hodgen 2007). There is limited evidence about the effect of rearing systems on VOCs detected in meat from suckling light kids. However, there are some studies on suckling light lambs (Osorio et al. 2008; Wilches et al. 2011). In agreement with these authors, we demonstrated that the magnitude of the effect of the rearing system depended mainly on the breed, because breeds that accumulate fat faster also accumulate greater amounts of VOCs (Wilches et al. 2011).

VOCs typically derived from lipid oxidation, such aldehydes, were more abundant in NM than those in MR (Osorio et al. 2008). These VOCs originated from auto-oxidation of fatty acids and the phospholipids of meat. Therefore, pentanal and hexanal were derived from linoleic and arachidonic acid, heptanal and octanal from oleic and linoleic acid, and nonanal from oleic acid (Shahidi 1998; Calkins and Hodgen 2007). The presence of linear aldehydes is important because these VOCs have low odour thresholds (Drumm and Spanier 1991) and their aromas are generally described as fruity or similar to fresh-cut grass. This fact was in agreement with the positive correlations found in this study between hexanal and the acceptability of flavour and overall acceptability. However, when aldehydes were studied in beef, the descriptors changed from desirable (fatty, meaty) to less desirable (rancid, painty, herbal) when the concentration of aldehydes in meat increased (Bewer and Vega 1995). Lean meat generates fewer aldehydes, and the descriptors should be positive. On the other hand, there are undesirable VOCS, including some medium-length branched-chain fatty acids such as the 4-methyloctanoic, 4-methylnonanoic and 4-ethyl analogues. These VOCS are responsible for the disgusting 'muttony' and 'sheepy' odour and are not found in suckling light kids because they appear upon puberty (Young and Braggins 1998). However, butyric acid appeared in the Guadarrama kids. The aldehydes 2-methyl propanal, 2-methyl butanal and 3-methyl butanal are generated in the Strecker degradation of valine, leucine and isoleucine, respectively, and have been reported to contribute considerably to the overall flavour of meat products (Andrade et al. 2010). 2-methyl propanal has been associated with barnyard odour (Frank et al. 2017), while 3-methyl butanal has been associated with ripened flavour (Careri et al. 1993).

Although hexane appeared in high amounts, hydrocarbons make minimal contributions to desirable or undesirable flavours (Drumm & Spanier, 1991). Additionally, some benzene-derived VOCs (toluene, p-xylene, o,m-xylene) have been detected (Wilches et al. 2011). The effect of the breed on toluene was high since it was detected in Churra but not Castellana suckling lambs irrespective of the rearing system (Wilches et al. 2011). Additionally, Vasta et al. (2012) found toluene in milk from grazing and stall-fed ewes.

The ketone 3-hydroxy-2-butanone was indicative of MR, and it is thought that it adds buttery notes (Montel et al. 1998). Other minority VOC were also found in suckling light lambs such as 1-pentanol (Vieira et al. 2012). Ethyl acetate has a positive relationship with barnyard odour (Frank et al. 2017). Alkyl pyrazines such as 2,5 dimethyl pyrazine have a very low odour threshold (Fors and Olofsson 1985). This pyrazine is a heterocyclic product from the later stages of the Maillard reactions and comes from the condensation of some amino acids and fructose. Dimethyl pyrazines appear more frequently in well-done grilled meat than they do in roasted meat (Chen and Ho 1998). 2-pentyl furan was detected in almost every breed and rearing system of this study. This compound was also detected in cooked pork but not in beef (Ho et al. 1978). 2-pentyl furan was also found in suckling lambs fed MR (Morán et al. 2014). This VOC is associated with beany, grassy (Drumm and Spanier 1991) and liver (Frank et al. 2017) flavour.

The degradation of sulphur-containing amino acids and thiamine generated in the Strecker degradation produces sulphur-containing compounds such as carbon disulphide and hydrogen sulphide. These compounds are important because they have very low odour thresholds (Mottram 1998). The concentration of sulphur-containing compounds is not affected by the rearing system of suckling lambs (Osorio et al. 2008). The most dominant sulphur compound in meat volatiles is hydrogen sulphide (Nixon et al. 1979). However, hydrogen sulphide was not found in suckling lambs or kids because this VOC is mainly in fat. Therefore, meat from suckling light small ruminants had a very low amount of intramuscular fat. Moreover, some authors proposed that high-pH meat, such as kid meat (Ripoll et al. 2012), is less flavourful (Young et al. 1993), because proteolysis and lipolysis operate more favourably at a lower pH (Young et al. 1993; Young and Braggins 1998). However, carbon disulphide has been detected previously on suckling lamb meat (Vieira et al. 2012). Carbon disulphide has been described as having a pleasant and sweet odour (Holleman et al. 2001). The lack of correlation between minority VOCs and sensory data could be because differences between rearing systems were not sufficiently large to have had an impact on flavour (Vieira et al. 2012).

Consumer preference for meat from different rearing systems

There is scarce information about the sensory differences between rearing systems on suckling light kids or lambs. Moreover, information provided is not conclusive. In agreement with the results of this study, the acceptability of flavour and overall acceptability of light kids fed NM were greater than those of kids fed MR (Alcalde et al. 2013). Napolitano et al. (2002) reported that panellists were able to differentiate between suckling lamb meat from NM and MR (information on product preferences and differential sensory properties was not available), but other authors reported that a semi-trained panel could not find differences between rearing systems (Osorio et al. 2008). In agreement with the results of this study, significant correlations have been reported by consumers of European countries between overall appraisal and flavour of lamb and suckling kid meat (Dransfield et al. 2000; Font I Furnols et al. 2006). However, preference or acceptability of meat is influenced by cultural aspects and consumption habits (Bernués et al. 2012). Dransfield et al. (2000) demonstrated a clear influence of the consumer's nationality on lamb preference. When non-professional panellists were used, the segmentation of people according to sociodemographic or psychographic characteristics was required to avoid misinterpretation of the results (Font I Furnols et al. 2006). Thus, the perception of flavour decreased with age, and some authors reported a loss of sensory capabilities from 60 years of age (Rolls 1999). Other authors suggested that the loss of capabilities started at 40 years (Russell and Cox 2004). However, in this study, only the older people differentiated between rearing systems. This result could be explained by the familiarity with the meat, which is related to the frequency of consumption and involvement with kid meat. Consumers with great familiarity with meat and great frequency of consumption also had high involvement (Borgogno et al. 2015). Consumers with great involvement think that certain products are a reflection of their own image (Verbeke and Vackier 2004). Therefore, these consumers could magnify differences between rearing systems erratically. The consumers with great familiarity also showed high scores on flavour and tenderness (Borgogno et al. 2015). On the other hand, consumers with low involvement have been reported to take decisions spontaneously (Verbeke and Vackier 2004). However, in this study, people with a moderate consumption of meat showed more discrimination power between rearing systems than did the other consumers.

Conclusions

The influence of the rearing system on the volatile compounds of cooked meat from suckling light kids clearly depended on the breed. In general, terms, the use of milk replacers did not affect the percentage of linear aldehydes compared to that in natural milk. However, the major aldehyde, hexanal, was related to the use of natural milk, while hydrocarbons, such as hexane, were related to the use of milk replacers. In addition, hexanal correlated positively with the acceptability of flavour and overall acceptability. Therefore, the acceptability of meat from suckling kids fed natural milk was greater for older consumers and people with a moderate consumption of meat. The other consumers did not differentiate the meat from kids raised on both systems. Other volatile compounds such as 2-methyl-pentane, 3-methyl pentane, 2-penthyl furan and 2-ethyl-1-hexanol were found in low amounts but correlated negatively with the overall acceptability of suckling kid meat. The use of consumers' psychographic characteristics helps to understand their preferences and avoid misleading conclusions from the sensory tests.

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Disclosure statement

The authors declare that they do not have any conflict of interest.

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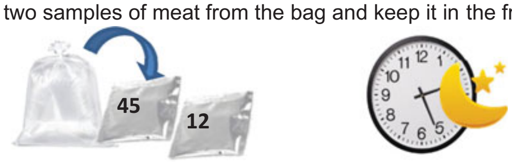
ANNEXE A

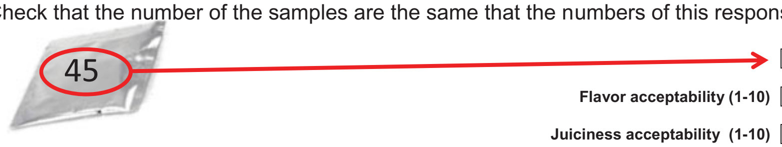
THANK YOU FOR YOUR COLLABORATION

We need that you assess TWO samples of kids' meat. Please, follow the instructions:

1. Take out the two samples of meat from the bag and keep it in the fridge overnight.



2. Check that the number of the samples are the same that the numbers of this response form.



	45	12
Flavor acceptability (1-10)		
Juiciness acceptability (1-10)		
Overall acceptability (1-10)		

3. Unwrap the samples carefully and do not mixed it.

4. Grill the meat without condiments such as salt or spices.
5. Taste it and score it from 1 (very low acceptability) to 10 (very high acceptability).
6. Finally, answer some questions about you.

Please score the meat from 1 (very low acceptability) to 10 (very high acceptability).

Flavor acceptability (1-10)		
Juiciness acceptability (1-10)		
Overall acceptability (1-10)		

Some information about you.

Gender	*Man*	
	Woman	

Age	*≤25*	
	26-40	
	41-55	
	>55	

Preference for meat	*High*	
	Medium	
	Low	

Frequency of meat consumption per week	*2 times or less*	
	From 3 to 6 times	
	More than 6 times	

Did you tasted the kid meat before the test?	*SI*		*NO*	