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FATTY ACID COMPOSITION OF LIPID STORES OF CAPTIVE EUROPEAN QUAILS (*COTURNIX C. COTURNIX*) IN SPRING

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ABSTRACT

There is a great variability in migratory and reproductive phenotypes of European quail, Coturnix c. coturnix, *that allows us to distinguish between different palearctic populations, namely in the western part of its breeding range. Consequently, sub-populations of different physiological statuses may overlap, especially in the median part of the distribution range of the species (e.g. in Portugal). Until now only morphophysiological criteria (the width of the subcutaneous pectoral lipid band and the moult stage) have been used to distinguish between different physiological stages but they were insufficient concerning the distinction of migratory statuses. In February-April 1993, we studied the fatty acid composition of lipid stores of 31 captive males, maintained under a short (n = 12) or long (n = 21) photoperiod after a winter sexual rest, as a new criterion. We collected subcutaneous lipid (triacylglycerol) samples in the interclavicular or furcular region in birds characteristic of each spring stage of the life cycle (wintering, fattening, migration and breeding). Fatty acids were separated and identified by gas-liquid chromatography (GLC). In all stages, the major fatty acid was oleic acid [C18:1(n-9)] (about 50%), followed by palmitic acid (C16:0) (20-23%), linoleic acid [C18:2(n-6)] (11-20%), palmitoleic acid [C16:1(n-7)] (6-10%), stearic acid (C18:0) (4-6%) and cis-vaccenic acid [C18:1(n-7)] (about 2%). Fatty acid composition of the triacylglycerols collected in the wintering stage was different from that of the other stages, and especially from that of the fattening stage. In contrast to the fattening stage, the wintering stage was characterised by higher percentages of stearic, linoleic and palmitic acids, and by lower percentages of palmitoleic and oleic acids. The other stages showed a considerable overlap of their fatty acid profiles. However, there was a similarity between the profiles of the migratory and fattening stages, and also between the breeding and wintering stages. The fatty acid composition may vary with various factors (food, absorption, interactions between acids, etc.), but, in the fattening and migration stages, the birds have a considerable enzymatic capacity to increase the unsaturation degree of the triacylglycerols. Then, to be used as a criterion of their migration status, the fatty acid composition analysis of the lipid stores must be further investigated.*

I. INTRODUCTION

The European quail, *Coturnix coturnix coturnix*, is the only migratory phasianid in Europe with sub-Saharan wintering areas and European breeding areas. But the annual cycle appears to be more complex than the classic alternation: winter sexual rest followed by spring migration, summer breeding and autumn migration. In fact, at least in the western part of the species breeding range, a great variability of migratory and reproductive phenotypes has been observed (GUYOMARC'H and SAINT-JALME, 1990; SAINT-JALME, 1990; SAINT-JALME and GUYOMARC'H, 1990; GUYOMARC'H, 1992). Therefore, it is necessary to understand the precise migratory movements of the European quail, especially in the intermediate areas of its home range.

In Portugal, during spring and autumn, it is possible to find individuals (or sub populations?) with completely different migratory statuses. For example, in spring one may find four classes of individuals corresponding to different migratory statuses. The first class includes individuals that have wintered and will reproduce in Portugal and show an advanced sexual development; some of them have no significant fat stores, but some others do. The second class includes individuals that, in Portugal, have wintered and are preparing to migrate to North European breeding areas, and where they are storing considerable amounts of fat. In the third class, one finds individuals that have arrived from North Africa or even from Sahel territories, that will reproduce in Portugal and still may have high quantities of fat stores. And, finally, individuals that arrive from the same regions and are in transit to North European breeding areas with great amounts of fat stores, form the fourth class. During autumn a similar situation could be found, but in an opposite migratory direction. To better understand these movements, it is important to establish methods to assess the migratory status of the European quail. Nowadays the information obtained by morphophysiological criteria used by several authors, such as the width of the subcutaneous pectoral lipid band (which means "lipid quantity") and moult stage, is insufficient.

Migration involves a succession of behavioural and physiological adjustments to changes in climate and ecology, many of which are not thoroughly understood (RAMENOFSKY *et al.,* 1995). Physiological adjustments include hormonal function changes and plasma level variations of prolactin (SAINT-JALME, 1990; BOSWELL *et al.,* 1995), corticosterone (RAMENOFSKY *et al.,* 1995) and luteinising hormone (SAINT-JALME, 1990; BOSWELL *et al.,* 1995). Furthermore, in migrant birds, the high cost associated with the migratory flight is balanced by the generalised accumulation of lipids, that will be used as "fuel" (ODUM, 1965; MOREAU and DOLP, 1970; BLEM, 1976; BAIRLEIN, 1985; NAPOLITANO and ACKMAN, 1990; BERTHOLD and TERRIL, 1991; LINDSTRÖM, 1991; LINDSTRÖM and ALERSTAM, 1992; ALERSTAM, 1993; LINDSTRÖM and PIERSMA, 1993). Consequently, there is a high capacity for rapid lipogenesis and lipolysis of the adipose tissue of migrant birds (ODUM, 1965), with triacylglycerols as its principal component (BLEM, 1976; LEHNINGER, 1981; CHRISTIE, 1982; NAPOLITANO and ACKMAN, 1990; COBOS *et al.,* 1994). Thus, one could expect the occurrence of seasonal changes in the fatty acid composition (which means "lipid quality") of lipid stores in migrant birds.

The aim of this paper is to analyse and compare the fatty acid composition of lipid stores in captive quails at different spring stages (i.e. physiological stages) of their life cycle (wintering, fattening, migrating and breeding) to establish a useful tool to clearly define the migratory status of the individuals.

II. MATERIAL AND METHODS

II.1. EXPERIMENTAL CONDITIONS

Thirty-three adult males of European quail from a reference strain from the South-West of France and reared in the laboratory under the natural photoperiod of Rennes (latitude 48 °N) (SAINT-JALME, 1990) were placed in individual cages (25x20x15 cm) from 22 February until 30 April 1993. A first group of 21 males was submitted to an artificial long photoperiod, 14.30:9.30 LD (14 hr and 30 min of light, and 9 hr and 30 min of dark), simulating the increasing spring photoperiod. A second group of 12 males was submitted to an artificial short photoperiod, 10:14 LD, simulating winter conditions. Neon lights, that provide 500 lux at 1 m, were used for that purpose.

Throughout the experiment the birds were given a choice between two kinds of food: a mixture of seeds of *Triticum aestivum, Panicum miliaceum, Phalaris canariensis* and *Festuca pratensis* (2:1:1:1 volumes), and a commercial pellet, based on a mixture of cereals supplemented with animal protein.

II.2. DATA COLLECTION

Characterization of the physiological stages

To characterize the physiological stages we used three indicators. The length of the cloacal vent which is strongly correlated to the development of the reproductive organs (GUYOMARC'H, 1985; SAINT-JALME, 1990) was measured twice a week. The width of the subcutaneous pectoral lipid band which is strongly correlated to the total corporal accumulated lipids (SAINT-JALME *et al.*, 1987; SAINT-JALME, 1990) was also measured twice a week. The nycthemeral locomotor activity which changes from diurnal to nocturnal activity at the time of migration (HEMON *et al.*, 1986) was continuously recorded using infra-red detectors (SAINT-JALME, 1990).

These indicators allowed us to define four physiological stages. In the wintering stage, there is no sexual development, nor fat deposition, and the birds show a low level of exclusively diurnal activity. In the fattening stage, quails show a high level of diurnal activity corresponding to a great energy intake (COMBREAU, 1992), and the width of the subcutaneous pectoral lipid band increases constantly together with a slight increase in the sexual index (SAINT-JALME, 1990). In the migration stage, the nightly recorded infra-red beam cuts (impulses) exceed 500, indicating an intensive nocturnal restlessness lasting for several days or weeks without any additional fat deposition. In the breeding stage, there are a measurable development of reproductive organs (cloacal index up to 5 mm), a fat index generally quickly decreasing, the birds become diurnal again, and nocturnal activity appears only in some males in the last hours of the night as an anticipation of sunrise (DEREGNAUCOURT, 2000).

The first stages of sexual development are indicated in both sexes by a progressive lengthening of the cloacal vent. It begins very early after the winter solstice and even before (GUYOMARC'H *et al.*, 1990; FONTOURA and GONÇALVES, 1996; FONTOURA *et al.*, 2000). Consequently, among the 12 males submitted to a short photoperiod, only 4 were retained as true wintering birds. Among those submitted to a long photoperiod (n = 21), some were sampled

at two (n = 7) or three (n = 2) different stages; the others (n = 12) were sampled only once. Therefore, in total we have 36 subcutaneous lipid samples (Table I): 4 representing the wintering stage, 6 the fattening stage, 12 the migration stage and 11 the breeding stage.

TABLE I

Fatty acid composition (% of total fatty acids) of subcutaneous lipid samples (triacylglycerols) of captive males of European quail, *Coturnix coturnix coturnix*, in relation to physiological stages in spring. n = number of samples where a given fatty acid was quantified.

TABLEAU I

Composition (en % du total des acides gras, moyenne ± écart type) en acides gras des échantillons de lipides sous-cutanés (triacyl-glycérols) prélevés sur des mâles de cailles des blés, *Coturnix coturnix coturnix*, en fonction du stade physiologique (hivernage, engraissement, migration, reproduction) au printemps. n = nombre d'échantillons dans lesquels un acide gras donné a été quantifié.

Fatty acid	Percentage of the total fatty acids (mean ± SD) in the stage of			
	Wintering %	Fattening %	Migration %	Breeding %
Meristic C14:0	0.51 (n=1)	0.64±0.13 (n=6)	0.65±0.12 (n=11)	0.70±0.18 (n=10)
Meristoleic C14:1(n-5)	1.06 (n=1)	0.22±0.06 (n=5)	0.18±0.05 (n=5)	0.17±0.06 (n=4)
Palmitic C16:0	22.84±1.37 (n=4)	22.26±2.73 (n=6)	20.48±1.55 (n=12)	20.37±1.63 (n=11)
Palmitoleic C16:1(n-7)	5.65±1.47 (n=4)	9.80±0.72 (n=6)	7.80±0.83 (n=12)	6.73±1.37 (n=11)
Stearic C18:0	5.77±0.66 (n=4)	4.08±0.70 (n=6)	4.74±0.60 (n=12)	4.83±0.47 (n=11)
Oleic C18:1(n-9)	44.16±2.40 (n=4)	48.90±2.58 (n=6)	48.32±3.37 (n=12)	47.17±3.30 (n=11)
Cis-vaccenic C18:1(n-7)	1.39±0.28 (n=3)	1.78±0.44 (n=6)	1.88±0.31 (n=11)	1.83±0.19 (n=10)
Linoleic C18:2(n-6)	19.64±1.11 (n=4)	10.99±1.39 (n=6)	15.14±1.65 (n=12)	17.07±2.88 (n=11)
Linolenic C18:3(n-3)	0.38 (n=1)	0.65±0.10 (n=6)	0.62±0.12 (n=11)	0.61±0.13 (n=11)
Arachidonic C20:4(n-6)	1.20 (n=1)	-	-	-
Others* (∑ means)	0.3	1.24	1.56	1.39
Totals (∑ means):				
Saturated	29.12	27.40	26.20	26.41
Unsaturated	73.78	73.18	76.00	74.79
Monounsaturat.	52.46	61.36	60.00	56.67
Polyunsaturated	21.32	11.82	16.00	18.12

* Includes C12:0, C15:0, C16:1(n-9), iC17:0, aiC17:0, C17:0, C17:1(n-9), C20:0, C20:1(n-11), C20:2(n-6), C20:3(n-3), C20:5(n-3), C21:0, C22:3(n-3), and C22:6(n-3), each one representing < 0.5% of the total fatty acids.

* Comprend C12:0, C15:0, C16:1(n-9), iC17:0, aiC17:0, C17:1 (n-9), C20:0, C20:1(n-11), C20:2(n-6), C20:3(n-3), C20:5(n-3), C21 :0, C22:3(n-3), et C22:6(n-3), chacun représentant < 0,5 % du total des acides gras.

Sampling of subcutaneous lipids

We used a new method to sample subcutaneous lipids. Some feathers were extracted from the furcular region and this area was disinfected with alcohol. Then a short incision (1-1.5 cm) in the skin was made to expose the fat. Approximately 0.2 g of fat was surgically removed and the incision was sutured with surgical sterile thread. An antiseptic cicatrizant powder was applied. The lipid samples were stored in plastic tubes, closed under nitrogen atmosphere and immediately frozen at -50 °C for subsequent analysis.

This method is very effective since a great amount of fat is accumulated in the furcular region. Besides, as it only involves a small cut in the skin, birds do not need to be anaesthetised. All the birds used in the experiment quickly recovered and, in some cases, we were able to sample the same bird at two or three different stages.

Analysis of triacylglycerol fatty acid composition

Total lipid extraction was done by the Bligh and Dyer method (WATANABE, 1988) and lipids were kept in a chloroform solution for fatty acid determination. Fatty acid methyl esters (FAME) were prepared by transesterification with a KOH (2N) methanolic solution according to the method described in AFNOR NFT 60-233 (AFNOR, 1993), and analysed on a CHROMPACK CP9001 gas-liquid chromatograph equipped with a FID (temperature: 300 °C) and a fused silica capillary column (25 m long x 0.22 mm i.d.) filled with BPX70. Nitrogen was used as the carrier gas at a flow rate of 2 ml/min. The oven temperature was increased gradually at a rate of 15 °C/min from 60 °C to 100 °C. After one minute at 100 °C, the temperature continued to increase until 250 °C was reached. This temperature was maintained during 5 min. Injector temperature was 280 °C, and the FAME were identified using individual standards or FAME mixtures of well-established composition.

II.3. DATA ANALYSIS

The lipid samples, based on the 10 major fatty acid percentage values, were ranked by a principal component analysis (SNEATH and SOKAL, 1973) using the routines of NT-SYS (PC-version 1.5) program (RHOLF, 1989).

III. RESULTS

Oleic acid [C18:1(n-9)] was the major fatty acid representing about 44-49% of the total fatty acids (Table I), followed by the palmitic (C16:0) (20-23%), linoleic [C18:2(n-6)] (11-20%), palmitoleic [C16:1(n-7)] (6-10%), stearic (C18:0) (4-6%) and cis-vaccenic [C18:1(n-7)] (1-2%) fatty acids. These six fatty acids represented about 98-99% of the total fatty acids at all stages. The remaining fatty acids were present in very low percentages. Saturated fatty acids were highest at the wintering stage. Among unsaturated fatty acids the monounsaturated fatty acids were lowest at the wintering stage and highest at the fattening and migration stages. In contrast, polyunsaturated fatty acids were highest at the wintering stage and lowest at the fattening stage.

The variability among samples expressed by the principal component analysis (Figure 1) is mainly represented by the two first principal components representing 59,19% of the variability (r = 0,73). The samples of the wintering males (A, negative values for axis 1) are clearly separated from the samples of the other groups, because of their higher than average percentages in stearic (C18:0), linoleic [C18:2(n-6)] and palmitic (C16:0) acids, and to their lower percentages in oleic [C18:1(n-9)], cis-vaccenic [C18:1(n-7)], palmitoleic [C16:1(n-7)], miristic (C14:0), palmito-vaccenic [C16:1(n-9)] and linolenic [C18:3(n-3)] acids. The samples of the fattening males (B) appear on the opposite side (positive values for axis 1). They are characterised by inverse percentage values of the mentioned fatty acids. This group partially overlaps the groups formed by the samples of migrant and breeding males. Nevertheless, the fatty acid composition of the samples of breeding males seems to be more similar to that of the wintering males. In contrast, the fatty acid composition of the samples of migrant birds is closer related to that of the fattening males. Samples "X" (n = 3) were excluded from the analysis interpretation, because it was impossible to clearly define the corresponding physiological stages.

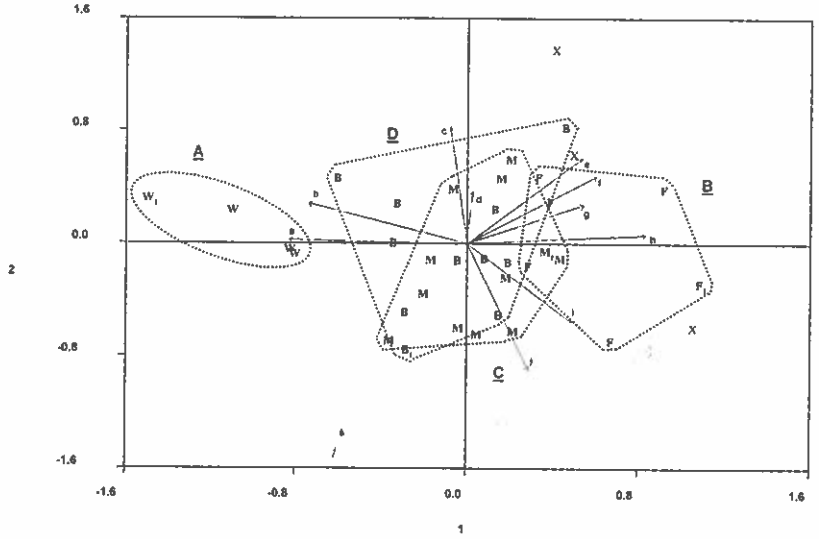

Figure 1: Distribution of 36 subcutaneous lipid samples (characterized by the composition in 10 fatty acids) and representation of eigenvectors (fatty acids) in the plane of the two first principal axes 1 and 2, grouped according to physiological stage. Males of European quail, *Coturnix c. coturnix*, maintained in captivity (n = 33) in February-April 1993. Samples: A: wintering ("W", n = 4), B: fattening ("F", n = 6), C: migrant ("M", n = 12), D: breeding ("B", n = 11); "X": physiological stage not clearly defined (n = 3); acids: a: stearic (C18:0), b: linoleic [C18:2(n-6)], c: palmitic (C16:0), d: meristoleic [C14:1(n-5)], e: meristic (C14:0), f: C16:1(n-9), g: linolenic [C18:3(n-3)], h: palmitoleic [C16:1(n-7)], i: cis-vaccenic [18:1(n-7)], j: oleic [C18:1(n-9)].

Figure 1 : Distribution des 36 points-échantillons de lipides sous-cutanés (caractérisés par leur composition en 10 acides gras) et représentation des points-variables (acides gras) dans le plan des deux premiers axes principaux 1 et 2 de l'analyse en composantes principales, encerclés en fonction du stade physiologique. Les cailles des blés (*Coturnix c. coturnix*) mâles (n = 33) avaient été maintenus en captivité en février-avril 1993. Échantillons : A : hivernage ("W", n = 4), B : engraissement ("F", n = 6), C : migrateur ("M", n = 12), D : reproduction ("B", n = 11) ; "X" : stade physiologique pas clairement défini (n = 3 ; acides : a : stéarique (C18:0), b : linoléique [C18:2(n-6)], c : palmitique (C16:0), d : méristoléique [C14:1(n-5)], e : méristique (C14:0), f : C16:1(n-9), g : linolénique [C18:3(n-3)], h : palmitoléique [C16:2(n-7)], i : cis-vaccénique [18 :1(n-7], j : oléique [C18:1(n-9)].

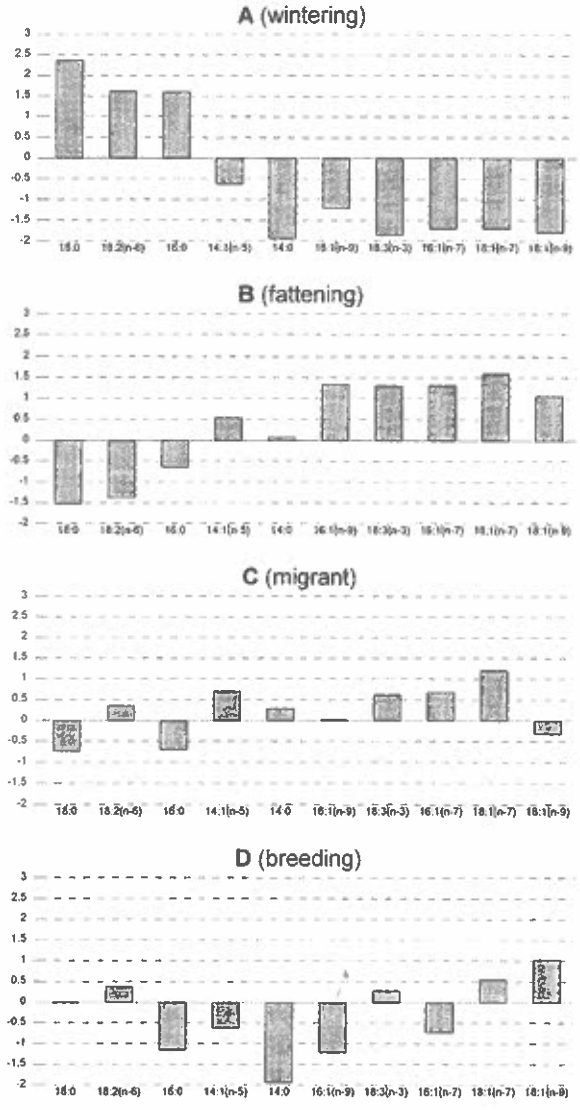

Figure 2: Fatty acid profiles of subcutaneous lipid samples (triacylglycerols) of four captive males of European quail, *Coturnix c. coturnix,* according to their physiological stage. On the y axis, a positive value means a higher percentage than the average estimated for all samples, and a negative a lower percentage. A: sample W1, B: sample F1 , C: sample M1, D: sample B1. Acids, from left to right: stearic (C18:0), linoleic [C18:2(n-6)], palmitic (C16:0), meristoleic [C14:1(n-5)], meristic (C14:0), C16:1(n-9), linolenic [C18:3(n-3)], palmitoleic [C16:1(n-7)], cis-vaccenic [18:1(n-7)], oleic [C18:1(n-9)].

Figure 2 : Profils en acides gras des échantillons de lipides sous-cutanés (triacyl-glycérols) de quatre mâles de cailles des blés, *Coturnix c. coturnix,* élevés en captivité, en fonction du stade physiologique. Une valeur positive sur l'axe des y indique un pourcentage plus élevé que le pourcentage moyen estimé pour tous les échantillons, et une valeur négative un pourcentage plus faible. A : échantillon W1, B : échantillon F1, C : échantillon M1, D : échantillon B1 . Acides, de gauche à droite : stéarique (C18:0), linoléique [C18:2(n-6], palmitique (C16:0), méristoléique [C14:0(n-5)]), méristique (C14 :0), C16 :1(n-9), linolénique [C18:3(n-3], palmitoléique [C16:12(n-7], cis-vaccénique [18:1 (n-7)], oléique [C18 :1[n-9].

Fatty acid profiles of individual samples allow to better understand the differences among, and tendencies of, physiological stages (Figure 2). In these profiles, a positive value means a percentage higher than the average estimated for all samples, and a negative a lower percentage. For example the profile for the wintering male shows higher percentages of palmitic acid, stearic acid and linoleic acid, and lower percentages for all other fatty acids, whereas the profile for the fattening male shows opposite values for the same fatty acids.

IV. DISCUSSION

IV.1. FATTY ACID COMPOSITION IN RELATION TO THE PHYSIOLOGICAL STAGES

In general, the fatty acid composition of subcutaneous lipids that were analysed in this study on the European quail is similar to that described for several species of birds. For these species more than 90% of the total fatty acids are composed by fatty acids with 16 and 18 carbon atoms (CALDWELL, 1973; BLEM, 1976; LEHNINGER, 1981; CHRISTIE, 1982; NAPOLITANO and ACKMAN, 1990; COBOS *et al.*, 1994; CONWAY *et al.* 1994).

According to several authors (HAZELWOOD, 1972; CALDWELL, 1973; BLEM, 1976; CONWAY *et al.*, 1994) the identification of migrants and nonmigrants based on fatty acid composition is a controversial subject that still remains to be clarified. In fact, our results are insufficient to distinguish between breeding and migrant males by their fatty acid profiles. In contrast, wintering and fattening males present distinct fatty acid profiles: the first group is characterized by higher percentages of palmitic, stearic and linoleic acids, and the second one by higher percentages of oleic and palmitoleic acids.

CONWAY *et al.* (1994) have analysed the lipid composition of breeding and autumn-migrating wood thrushes, *Hylocichla mustelina.* As in the present study, these authors found that percentages of oleic acid were higher and percentages of palmitic, stearic and linoleic were lower in autumn-migrating birds compared to breeding birds.

The fatty acid composition of the lipid stores of wild birds has been analysed only in a few studies (WALKER, 1984, *in* ODUM, 1965; CALDWELL, 1973; BLEM, 1976; NAPOLITANO and ACKMAN, 1990; CONWAY *et al.*, 1994) where triacylglycerols were usually not separated from phospholipids. However, BLEM (1976) reported that this fact probably does not affect the results since the removed fat was subcutaneous and mainly composed by triacylglycerols.

IV.2. FATTY ACID COMPOSITION FACTORS

Several factors may affect the fatty acid composition of the lipid stores (BLEM, 1976; COBOS *et al.*, 1994) such as sex (there could be differences between sexes in lipid metabolism), type and quantity of ingested food, time of lipid sampling, and species (there could be differences in retention and absorption of lipids between species). Furthermore, digestion, absorption, physiological transport and metabolism of lipids are dependent on other factors, such as the length of the carbon atom chain composing the fatty acids,

the degree of unsaturation of fatty acids, and possible interactions among them (FLANZY *et al.,* 1968, HAMILTON and MCDONALD, 1969, JEFFCOAT and JAMES, 1984, in COBOS *et al.,* 1994; HASMIN and BABYAN, 1978, in HAYES *et al.,* 1994; MABAYO *et al.,* 1994).

Palmitic, linoleic and oleic acid compositions

COBOS *et al.* (1994) reported that palmitic acid (C16:0) is one of the most changing unsaturated fatty acids depending on the diet fed. According to OUHAYOUN *et al.* (1987), cited by COBOS *et al.* (1994), it could be negatively influenced by the presence of oleic acid.

Linoleic acid [C18:2(n-6)] is an essential fatty acid (birds cannot synthetize it) that appears in corporal triacylglycerols due to exogenous supply. This fatty acid also appears in considerable percentages in phospholipids which have higher percentages of polyunsaturated fatty acids (LEHNINGER, 1981; CHRISTIE, 1982) and is mobilized to form araquidonic acid, which allows prostaglandin formation (a set of substances with hormonal and regulatory functions) (LEHNINGER, 1981).

To understand the variation of oleic acid [C18:1(n-9) in triacylglycerols one must not only take into account its synthesis from stearic acid by formation of a double bond on 9-10 position, but also the fact that a high percentage of linoleic acid (as a consequence of diets rich in this fatty acid) could lead to a decrease in oleic acid in the corporal lipids, and therefore, in triacylglycerols (COBOS *et al.,* 1994). This negative interaction between the two fatty acids would be due to the linoleic inhibition of the responsible enzyme for oleic acid synthesis (delta-9-desaturase).

MABAYO *et al.* (1994) reported that, in chickens, linoleic acid was not excreted at different levels in faeces, as long as oleic acid was excreted in a dependent way by diet concentration. These authors think that linoleic is better absorbed than oleic. It is generally accepted that the predominant mechanism in linoleic acid absorption, at high concentrations, would be simple diffusion (CHOW and HOLANDER, 1989, in MABAYO *et al.,* 1994; HAYES *et al.,* 1994). In chickens there would be a good utilisation of oleic acid (LING *et al.,* 1989, in MABAYO *et al.,* 1994), but linoleic acid would interfere in its absorption. This is due to a protein intermediary at the intestinal mucosa, resulting in different levels of excreted oleic acid.

Then, the observed differences between the wintering and fattening stages may , at least partially, be explained by food consumption and the interaction processes among the oleic, linoleic and palmitic acids. In fact, GONÇALVES (1994) has evaluated the food consumption of quails in experimental conditions and concluded that fattening males consumed mainly food rich in oleic and palmitic acids whereas wintering males preferred food rich in linoleic acid. It also must be noted that COMBREAU (1992) and COMBREAU and GUYOMARC'H (1992) reported a significant increase in daily energy and protein consumption between wintering and fattening stages. On the other hand, the energy content of fatty acids increases with chain length and decreases with unsaturation, and fatty acids with 18 carbon atoms provide a relatively great energy content per unit mass (BLEM, 1990, in CONWAY *et al.,* 1994). Oleic acid is a relatively high-energy fatty acid, with a low melting point, and its higher percentage at fattening and migration stages could be adaptive prior to a long distance migration, similarly to what CONWAY *et al.* (1994) suggested for the wood thrush.

Palmitoleic and stearic compositions

Palmitoleic acid [C16:1(n-7)] appears in lipid stores due to unsaturation of palmitic acid in the liver (KOUBA, 1993; COBOS *et al.*, 1994). Its considerable percentages (5-10%) at all stages suggests a certain capacity of the European quail to perform the unsaturation process. According to GUENTER *et al.* (1971, *in* COBOS *et al.*, 1994), palmitoleic synthesis would be submitted to a metabolic mechanism independent from its concentration in the diet and would instead be influenced by polyunsaturated fatty acid concentration. The recorded opposite variation in palmitoleic and polyunsaturated percentages, namely linoleic acid, throughout the stages may be explained by that interaction.

Concerning stearic acid (C18:0), COBOS *et al.* (1994) reported that, among unsaturated fatty acids, stearic seems to suffer little variations in corporal lipids due to the food source. An explanation to this may be its low rate of absorption (APGAR *et al.*, 1987, in HAYES *et al.*, 1994). JEFFCOAT and JAMES (1984, in COBOS *et al.*, 1994), reported that the degree of saturation of lipid stores is never very high due to the enzymatic regulatory activity (namely of delta-9-desaturase), which synthetizes oleic from stearic acid. HAYES *et al.* (1994, *in* HAYES *et al.*, 1994) reported that, in rats, *Rattus rattus,* about 50% of stearic acid supplied in diet was converted to oleic acid. This unsaturation process seems to have been partially responsible for stearic acid variation throughout the different stages, since the percentages of oleic acid increased when the percentages of stearic acid decreased and *vice-versa.*

Our results may also have been conditioned by some experimental factors. In fact, during the experiment, we realised that some samples were probably collected from birds that were in phases of transition. This may partially explain the overlap of the fatty acid profiles of birds in different physiological stages. In other respects, during the experimental period, the birds were not allowed to fly, which may influence the fatty acid composition.

V. CONCLUSION

We may conclude that the fatty acid composition variation is due to a complex conjugation of various factors: type and quantity of food consumed, different degree of absorption, interactions between fatty acids and a considerable enzymatic capacity to increase the unsaturation degree of triacylglycerols (mainly at fattening and migration stages). This capacity may be related to the migratory status.

At the moment, the described changes in fatty acid composition of lipid stores and their relationship with the different physiological stages, must be taken as indicators for future research. Some aspects need to be clarified to definitively evaluate the utility of this kind of analysis as a possible method to define the migratory status of European quail.

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COMPOSITION EN ACIDES GRAS DES RÉSERVES LIPIDIDIQUES CHEZ DES CAILLES DES BLÉS (*COTURNIX C. COTURNIX*) CAPTIVES AU PRINTEMPS

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MOTS-CLÉS : Caille des blés, *Coturnix coturnix coturnix,* captivité, printemps, statut migratoire, réserve lipidique, acide gras, cycle saisonnier, Paléarctique occidental.

RÉSUMÉ

La grande variabilité entre les phénotypes migratoires et reproducteurs de la caille des blés européenne, Coturnix c. coturnix, *nous permet de faire une distinction entre les différentes populations paléarctiques, notamment dans la partie ouest de l'aire de distribution. Ainsi, des sous-populations qui n'ont pas le même statut physiologique peuvent se chevaucher, surtout dans la partie médiane de la zone de distribution de l'espèce (par exemple au Portugal). Jusqu'à présent, seulement quelques critères morpho-physiologiques (la largeur de la bande de graisse pectorale sous-cutanée et le stade de mue) ont été utilisés pour caractériser les différents stades physiologiques, mais ils se sont avérés insuffisants pour mettre en évidence les stades migratoires. En février-avril 1993, nous avons étudié, comme nouveau critère, la composition en acides gras des réserves de graisse chez 31 mâles gardés en captivité et maintenus sous une courte (*n = *12) ou une longue (*n = *21) photopériode après le repos sexuel hivernal. Nous avons prélevé des échantillons de lipides (triacylglycérols) sous-cutanés, entre les clavicules ou au niveau de la fourchette, sur des oiseaux caractéristiques de chaque stade du cycle de vie printanier (hivernage, engraissement, migration et reproduction). Les acides gras ont été séparés et identifiés par chromatographie en phase liquide-gazeuse (GLC). À tous les stades, l'acide gras le plus important était l'acide oléique [C18:1(n-9)] (environ 50 %), suivi par l'acide palmitique (C16:0) (20-23 %), l'acide linoléique [C18:1(n-6)] (11-20 %), l'acide palmitoléique [C16 :1(n-7)] (6-10 %), l'acide stéarique (C18:0) (4-6%) et l'acide cis-vaccénique [C18 :1(n-7)] (environ 2 %). Le contenu en acides gras des triacylglycérols collectés pendant le stade hivernage a été différent de celui relevé au cours des autres stades, en particulier au cours du stade engraissement. Contrairement au stade engraissement, le stade hivernage était caractérisé par des pourcentages plus élevés d'acides stéariques, linoléiques et palmitiques, et par des pourcentages plus faibles d'acides palmitoléiques et oléiques. Pour les autres stades on a constaté un chevauchement considérable des profils individuels d'acides gras. Malgré cela, on a constaté une certaine similitude entre les profils du stade engraissement et du stade migratoire, ainsi qu'entre les profils des stades reproduction et hivernage. La composition en acides gras peut varier en fonction de divers facteurs (nourriture, absorption, interaction entre acides, etc.), mais, pendant les stades engraissement et migration, les oiseaux ont une très grande capacité à augmenter le degré de non-saturation des triacyl-glycérols grâce à leurs enzymes. C'est pourquoi, si l'on veut utiliser la composition en acides gras des réserves de graisse comme critère du statut migratoire, il faut poursuivre auparavant des recherches plus approfondies sur ce sujet.*