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Sows and piglets adjust their use of an outdoor paddock with season and piglet age during the first weeks of life in an organic farm

Anissa Jahoui [a,b], Jens Malmkvist [c], Lene Juul Pedersen [c], Blandine Lieubeau [b], Julie Hervé [b,1], Céline Tallet [a,1,*]

[a] PEGASE, INRAE, Institut Agro Rennes Angers, Saint Gilles 35590, France
[b] Oniris, INRAE, IECM, Nantes 44300, France
[c] Department of Animal and Veterinary Sciences, Aarhus University, Blichers Allé 20, Tjele 8830, Denmark

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ABSTRACT

Few studies have examined sows and piglets' use of outdoor access during their first weeks of life, when reared with access to a hut and a pasture as in the organic system. We studied whether the age of the piglets and the season of the year influenced the use of an outdoor area by piglets and the sow, and the use of indoor spaces. For this, the localisation of sows and their piglets inside and outside the hut was analysed on 16 sows and their litters during the summer and 16 others during the winter, by scan sampling, on days 2, 7 and 13 after parturition in an organic herd in Denmark. When inside the hut, the number of piglets in the creep area, next to the sow or other piglets was noted. All parameters were analysed by linear mixed-effects ANOVA models. Sows were less often observed outside the hut in the wintertime and during the mornings compared to later times of the day ($P<0.001$). Furthermore, the sows increased their outdoor use with the age of their litter ($P<0.001$). The season also influenced the piglet use of outdoor areas (winter < summer; $P<0.001$). Piglets that were observed outside for the first time were older (8.9±0.9 d) during winter than during summer (3.5±0.5 d). The proportion of piglets observed outside increased with age, with a significant Season x Age interaction ($P<0.001$). The proportion of observations where the sows and piglets were outdoors together increased with the piglets' age ($P < 0.001$). Sows' outing was correlated with summer ($R=0.3$) and winter ($R=0.2$) temperatures, unlike piglets, where outings were correlated only with summer temperatures ($R=0.3$, $P<0.001$). The proportion of piglets observed in the creep area was significantly affected by the age with a Season x Age interaction effect ($P<0.001$). Piglets were rarely observed lying alone inside the hut. The proportion of piglets in contact with the sow and other piglets inside the pen was influenced by a significant Age x Season interaction effect ($P<0.001$). We showed that piglets given access to an outside paddock gradually increase their use with age and don't go outside right away. Their first exit and the proportion of piglets outside depended also on the season. In general, a higher proportion of sows and piglets were observed indoor during the wintertime. Thus, sows and piglets adjust their use of outdoor paddock with season and piglet age during the first weeks of life.

1. Introduction

Currently in the European Union (EU), the majority of pigs are raised indoor on full slatted floors; less than 1 % are raised with some access to outdoor areas such as in organic farms (EPRS, 2020). An increasing number of EU citizens are concerned about animals' lacking outdoor and grass access and lacking opportunity to express their natural behaviour (Delanoue et al., 2018, Eurobarometer, 2023). In addition, animal husbandry is challenged on its acceptability by consumers who tend to change their eating habits, due to issues related to human health, animal welfare and environmental footprint (Alonso et al., 2020; Bushby et al., 2021).

A variety of systems allowing pigs to access outdoors does exist. Some farming systems allow animals to choose if they want to be in or outside, via access to a roofed outdoor run for example (Prunier et al., 2014) or a pasture (Leeb et al., 2019). All these outdoor systems may

* Corresponding author.
E-mail address: celine.tallet@inrae.fr (C. Tallet).
[1] last co-authorship

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have advantages as well as disadvantages for animal welfare. For weaned piglets, studies show that pigs with an outdoor access express a larger diversity of behaviours, being more active, and more explorative (Nakamura et al., 2011), expressing more positive social behaviours (Lau et al., 2015) and less agonistic behaviours (Blumetto Velazco et al., 2013), than piglets raised in conventional indoor conditions do.

The benefits of outdoor housing are less obvious for piglets during their early life, especially due to a higher risk of mortality (review of Schild et al., 2020). For example, piglet crushing – one main cause of neonatal mortality – has been reported more frequently in outdoor housing systems where sows are typically kept loose during farrowing and early lactation (Delsart et al., 2020). Furthermore, in systems with outdoor access, piglet mortality may increase due to reduced thermal comfort, since outside temperatures cannot be controlled, unlike in a closed barn. When temperatures are low, piglets can suffer from hypothermia (Rangstrup Christensen et al., 2018). Indeed, piglets are born without subcutaneous heat-generating brown adipose tissue and rather defend their core temperature by shivering and adapting their behaviour, changing their posture and proximity with littermates and the sow for heat transfer and milk intake (Herpin, 1989). This adaptive behaviour probably increases the risk of crushing by the sow (Hrupka et al., 2000). All these adaptations require energy leading to an increase in food intake with a risk of growth slowdown when piglets are exposed to long periods of cold (Herpin, 1989).

Additionally, too high temperatures may also constitute a challenge for the piglets, with extreme weather situations expected to increase with global climate changes (Renaudeau and Dourmad, 2022). At high temperatures, pigs are subjected to heat stress which challenges their ability to thermoregulate because, unlike most mammals, they have few sweat glands. The comfort temperature for sows is between 16 and 25°C, while the lower limit of the thermoneutral zone of newborn piglets is around 34°C (Herpin et al., 2022). At higher temperatures, pigs and specially gestating sows, use mud to decrease their internal temperature through wallowing (Bracke, 2011; Baert et al., 2022b). However, the well-developed adipose tissue of farm pigs prevents them from evacuating heat. As a consequence, to reduce heat production, pigs adjust their behaviour by decreasing their activity, lying down and reducing their feed intake, which negatively impacts their growth performance (Mayorga et al., 2019; Renaudeau et al., 2011).

In contrast, newly born piglets particularly suffer from cold stress since the lower limits of their thermoneutral zone is as high as 34–35°C right after birth (Herpin et al., 2002). In indoor well-controlled conditions, this can be dealt with by adding extra heat at the birth site, e.g. increasing room temperature (Pedersen et al., 2013) or floor heating (Malmkvist et al., 2006; Pedersen et al., 2007) or by adding heat into the creep area with a lamp (Titterington and Fraser, 1975).

We therefore presume larger effects of seasons' climatic conditions on sow and piglets' behaviours, when housed in less climate-protected conditions. In order to understand piglet's use of the outdoor space, we thought interesting to understand how they use the indoor space, and which factors drive piglets to stay indoors or go outside. The scientific literature provides only sparse knowledge on the indoors' and outdoors' use of piglets depending on the season and according to their age from birth to weaning (ex: Schild et al., 2018). In this project, we offered sows and their progenies access to a grassed outdoor on a voluntary basis and a protection in the form of a hut with deep straw bedding. The aim was to determine the factors influencing the use of outdoors and indoors spaces by piglets and the sow, in particular the age of piglets and the season of the year.

2. Material and methods

2.2. Animals and housing

Thirty-two litters were followed, issued from parity 2–6 TN70 sows (Topig Norsvin, https://topigsnorsvin.dk/) sired by Duroc or Landrace x Yorkshire boars (Danbred, https://danbred.com/, Denmark). The litters were distributed in 8 batches, four born during the summer (from June to August, in 2021 and 2022) and four during the winter (from mid-November to January, in 2021 and 2022) (Table 1). Seasons were defined according to the astronomical calendar marked by equinoxes and solstices. Summer corresponded to the months of June, July and August, and winter to December, January and February. Observations of one batch began in mid-November and continued until early December, thus it was considered part of winter.

Until weaning at approximately 49 days of age (41 days to 52 days), each sow and its litter were housed in an individual pen in a hut with access to an individual grassed outdoor space (Vanggaard Staldmontage, Denmark) (Fig. 1A). Piglets were supplemented with a feed product for piglets from week 2 after birth, and then with pelleting feed for weaned piglets two weeks before weaning. Food was always provided to sows and piglets inside the hut, in the morning (between 8 and 10 am), once a day. Each batch consisted of 4 sows in a single hut divided into 4 pens (each measuring 4 m^2) with straw bedding. The feeder and the water supply for sows and piglets were positioned inside each pen in a corner near the creep area only accessible to the piglets (Fig. 1B). In the opposite corner, a screened area introduced protection for the piglets from being crushed. Additionally, each pen was equipped with iron bars along each side to limit piglets' crushing by the sow. Finally, in each pen, two swing doors allowed access to outdoor. From birth to 9–11 days later, piglets' access to the outdoor area was limited to a smaller area (0.8 m x 2 m) using a for-yard barrier that only the sow could pass. Later on, the barriers were removed allowing full access to a 300 m^2 grassed outdoor area, with year-round grass coverage. Piglets from all litters could move freely from their outdoor area to the three adjacent ones.

For each batch, the four pens of the hut differed upon two housing factors: (1) the presence of a *pendulum* to support the sow lying down, and (2) the heating of the creep area. Creep area heating relied upon a lamp with an infrared bulb (150 W), turned on for 10 days from birth. All combinations of the factors coexisted at any time in the hut, pen 1: not heated creep area and no *pendulum*, pen 2: heated creep area and no *pendulum*, pen 3: not heated creep area and *pendulum*, and pen 4: heated creep area and *pendulum* (Fig. 1B).

The farmer locked the piglets into the creep area on day 1 (with day 0 as the day of farrowing of the first living piglet) for a few hours and piglets received iron, were vaccinated and males were castrated at the age of ~3 days. The sows were fed with commercial dry food according to their stage of lactation in close to *ad libitum* amounts.

2.3. Behavioural observations

For behavioural observations, each pen was video-recorded thanks to one video-camera (HIK Vision, Type DS-2CD2345FWD-I 2.8 mm Lense, PoE:12 volt, 0.5 A, 5Watt. Network Camera, China) fixed inside the hut. Another camera partly covered the outdoor area as well, including the smaller areas reserved for piglets before the age of 11 days. The videos were recorded continuously and saved from the day before parturition for the following analyses.

The behaviour of the sows and their piglets was observed by scan sampling during three periods [once around day 2 (2−3), once around day 7 (5−9) and once around day 13 (11−16)]. On each period, piglets were observed every 5 minutes for 2 h after the sunrise (morning); from 11h15 to 13h15 (noon), and for 2 h before the sunset (evening). The time of each sunrise and sunset per date was obtained from the astronomic calendar to organise the schedule of the observations for each day precisely.

At each scan, we recorded the localisation of the sows and their piglets (indoors *vs* outdoors). Sows were observed individually unlike piglets which were observed as a group so we noted the number of piglets inside and outside. We determined the age at which piglets were observed outside for the first time and the global presence outdoors (*i.e.* the small area until day 11, and the whole area thereafter). If piglets

Table 1
Descriptive parameters of each batch. Four litters, corresponding to the four treatments were included per batch. For each batch, mean (SD), minimum and maximum of the number of piglets/litter are reported.

Season	Summer				Winter			
Batch	06/21	07/21	06/22	08/22	11/21	12/21	01/22 (beginning)	01/22 (end)
Sow parity								
Mean (±SD)	3.5±1	3.8±1.7	2.3±0.6	2.8±1.0	3.8±2.8	5±1.6	3.3±1.5	4.8±1.7
Min	2	2	2	2	1	3	2	3
Max	4	6	3	4	7	5	5	7
Number of littermates								
Mean (±SD)	15.5±0.6	13±2.9	14.5±1.0	14.8±1.0	14.5±5.2	12.3±1.7	13.8±1.3	10.8±3.3
Min	15	10	13	14	7	10	12	7
Max	16	17	15	16	18	14	15	14

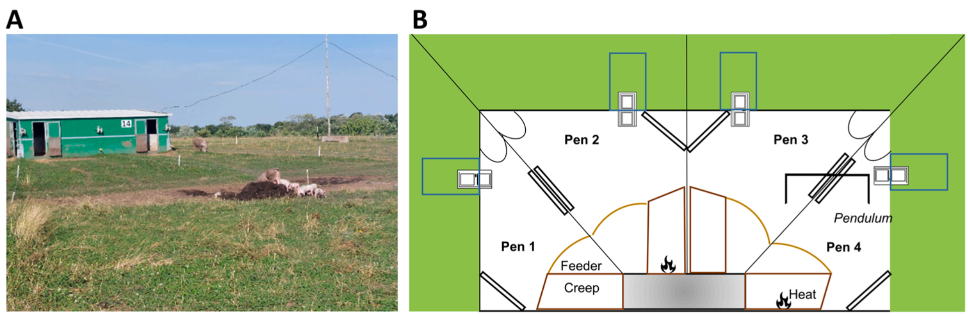

Fig. 1. The hut and its surrounding grassed outdoor area. Picture of the hut and the grassed outdoor area (A). Indoor organisation (B). Each pen (4 m^2) had a creep area (heated or not) (0.85 m^2), a feeder, an area protecting piglets (circles in corner), an anti-crushing barrier (rectangles on the sides) and doors leading to the outdoor area; two pens were also equipped with a pendulum. The outdoor area connected to each pen measured 300 m^2 but a smaller area (0.8 m x 2 m) was delimited until the piglets were 11 day-old of age. Figure not to scale.

were indoor, we also noted the numbers of individuals into the creep area, in contact with the sow, in contact with other piglets and alone. A piglet was considered in contact with another individual when it was located at a distance not exceeding its own width, whatever its posture (e.g. piglet walking, standing, lying down). Finally we could calculate the proportions of piglets for each position, by calculating an average proportion of piglets outside and inside (into the creep area or in contact with the sow or with other piglets). We studied also the simultaneous use of outdoor, by calculating the number of times where the sow and at least one of the piglets were outside out of the total number of observations outside. Definition of the measurements according to the ontologies is available in Supplementary Table S1.

2.4. Temperature, humidity and precipitation

Meteorological data (temperature, humidity and precipitation rate) were downloaded from the nearest official meteorological station located ~14 km from the farm (Danish Meteorological Institute weather station Tylstrup). All these data were averaged (± standard deviation) over the 2 hours of observation periods.

2.5. Statistical analyses

Statistical analyses were performed with R (version 2022.12.0, RStudio Team (2020)) using linear mixed-effects models ANOVA type 3 function ("lmer" package). We developed a model with the season (summer, winter), the age ([day 2–3], [day 5–9] and [day 11–16], the heated creep area (present/absent), the *pendulum* (present/absent) as fixed effects, and the batch number (n = 8) and the sow (n = 22), as random effects. Here, only the interaction between the season and the age was analysed since no effect of the heated creep area and the *pendulum* was found. The time of the day was first included but then removed from the model since no significant effect was found. The goodness of fit of all models (normality of residuals, homogeneity of variance and colinearity) was checked on visual plots. The estimated marginal means (emmeans) and the upper and lower limits of the 95 % confidence interval [IC95], calculated using the "emmeans" package, are reported in the text and represented graphically as emmeans [IC95] using GraphPad Prism software (version 9.3.1). Differences were considered significant at $P < 0.05$ and written in bold, while those at $P < 0.1$ were reported as tendencies. When the interaction effect was significant ($P < 0.05$), a Tukey's Honest Significant Difference *post-hoc* test was performed to search for relevant differences and the results are described in the Results section. To investigate the possible correlation between the frequency of sows and piglets going outside and meteorological data (outdoor temperatures and humidity), Spearman's rank correlation coefficients were calculated. To see if there were any seasonal differences in outdoor temperatures, humidity and precipitation values, t-tests were performed.

3. Results

3.1. Use of the outdoor space

3.1.1. Meteorological data

Outdoor temperature and humidity values were statistically different between summer and winter ($P < 0.001$). Mean temperatures were higher in summer than in winter, while humidity was higher in winter than in summer (Table 2). Precipitations were low during our observations and not different between the seasons ($P > 0.05$).

3.1.2. Use of the outdoor area by sows

The sows were on average of the observations significantly less observed outside the hut in the winter (16.3 ± 4.8 % of the observations) than during the summer (30.1 ± 4.8 % of the observations; $P < 0.01$). They were also less frequently observed outside during the mornings (sunrise: 17.2 ± 5.1 %) than later during the day (at noon: 23.5 ± 5.1 % and during the sunset: 29.2 ± 5.1 %) whatever the season, the treatment and the sow parity. Additionally, the use of the outdoor area by the sows increased with the age of their litters ($P < 0.001$;

Table 2
Measures of the temperatures of outside, of the humidity and of the precipitation according to the seasons of the study. Median, minimum and maximum, percentiles at 25 % and 75 %, mean (±SD) were given for the outdoor temperatures (°C), the humidity levels (%) and the precipitations rates (kg/m^2). The precipitation rates represented the amount of precipitation that was collected over seasons. Spearman's rank correlation coefficient have been indicated between frequency of sows and piglets going outside the hut and the temperatures of outside and the humidity according to the seasons.

	Temperature outside		Humidity		Precipitation	
	Summer	Winter	Summer	Winter	Summer	Winter
Number of values	144	132	144	129	142	129
Minimum	8.4	-3.4	52.7	37	0	0
25 % Percentile	14.3	1.8	69.7	82	0	0
Median	16.9	4.8	79.2	89.7	0	0
75 % Percentile	19.4	6.6	93	97.7	0	0
Maximum	26	9.5	100	100	0.5	0.5
Range	17.6	12.9	47.3	63	0.5	0.5
Mean (±SD)	16.8±3.6	4.3±2.7	80.2±13.6	87.1±13.1	0.03±0.1	0.04±0.1
Spearman r						
Sows	0.3	0.2	-0.04	-0.1		
Piglets	0.3	0.07	-0.01	0.02		
95 % confidence interval	0.09–0.4	0.03–0.4	-0.2–0.1	-0.3–0.07		
Sows						
Piglets	0.1–0.4	-0.1–0.2	-0.2–0.2	-0.1–0.2		
p value (two-tailed)						
Sows	**0.002**	**0.02**	0.6	0.2		
Piglets	**0.0009**	0.4	0.9	0.8		
Number of XY Pairs	144	129	144	144		

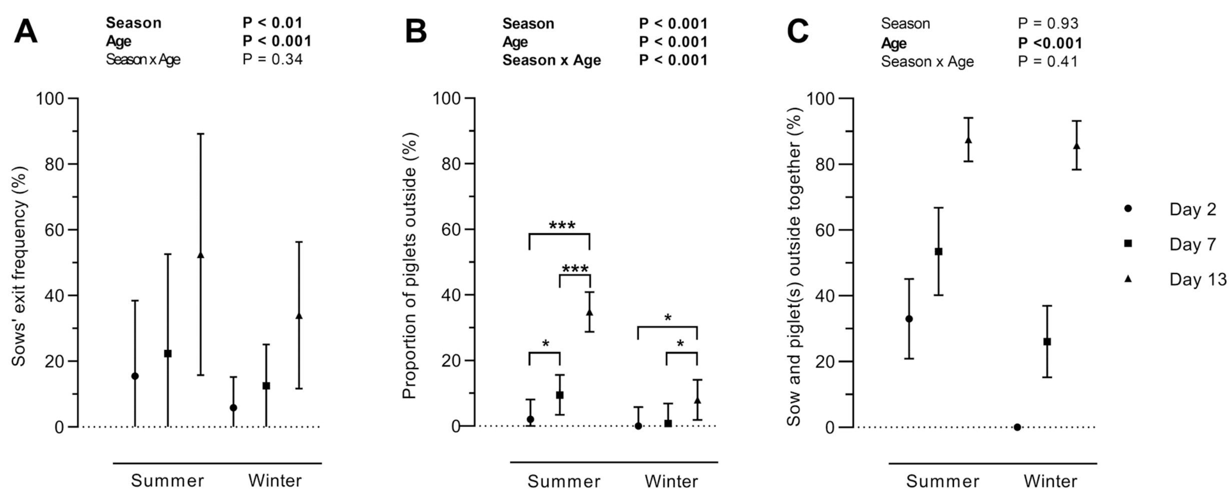

Fig. 2. Use of the outdoor area by the sows and their piglets. The proportions of the observations when the sows was outside (A), the proportion of piglets observed outside (B) and the proportion of observations when at least one piglet was found outside together with the sow (C) are represented (emmeans +/- [IC95]) according to the age of the piglets (day 2, day 7 and day 13) and to the seasons (summer and winter). Results of the post-tests are indicated: * P < 0.05, ** P < 0.01 and *** P < 0.001.

Fig. 2A).

3.1.3. *Use of the outdoor area by piglets*

The youngest age at which at least one individual piglet per litter was observed outside was significantly affected by the season (P < 0.001), but neither by the presence in the pen of a heated creep area nor by a *pendulum* (P > 0.05 for each factor). Piglets that were observed outside for the first time were older (8.9 ± 0.9 days; [min: 6; max: 14]) during the winter than during the summer (3.5 ± 0.5 days; [2 min; 6 max]).

When piglets were observed outside for the first time they were usually in groups independently of the season. The proportion of piglets observed together outside was on average 32 % during summer and 27 % during winter (non-significant, P = 0.43). Likewise, we detected no effect of the heated creep area and the *pendulum* (P > 0.05).

The proportion of piglets observed outside increased with the age and the season (P < 0.001), with a significant Season x Age effect (P < 0.001; Fig. 2B). On day 2, the proportion of piglets observed outside was similar in summer and in winter. Then, we observed a gradual increase of the proportion of piglets outside with age during summer, and only an increase of the proportion between day 7 and day 13 in winter. Finally, around day 13, a higher proportion of piglets used the outdoor area during the summer than during the winter (P < 0.001). Overall piglets spent more than 80 % of the observation time indoors, except during the summer, on day 13, when they were slightly less inside, i.e. 70 % of the time. In contrast to the sows, the proportion of piglets observed outside was independent of the time of the day (P = 0.43).

During the first two periods of observation (day 2 and day 7), the large majority of animals seen outside were sows (90 % of the outdoor observations). The synchronisation of outdoor use –i.e. the proportion of times where the sow and at least one piglet were outdoor together– increased with piglets' age (P < 0.001; Fig. 2C).

3.1.4. *Sow and piglet outdoors' use in relation to outdoor temperature and humidity*

Sows were seen outdoors more as winter (R = 0.2) and summer (R = 0.3) temperatures increased. Interestingly, the frequency of the piglets seen outside was positively correlated with the temperature in the summer only (R = 0.3; Table 2), not in the winter. For both sows and piglets, the outdoor use was not correlated with the humidity rate.

3.2. Use of the indoor space inside the hut

3.2.1. Use of the creep area

The proportion of piglets observed in the creep area was significantly affected by the age ($P < 0.01$) with a Season x Age effect ($P < 0.001$; Fig. 3). During the first week of lactation, there was no significant season effect. During the summer, a relatively constant proportion of the piglets was found inside the creep area (~15 %), however, there was a small significant difference between day 7 and day 13. During the winter, the proportion of piglets in the creep area remained constant between day 2 and day 7 (~30 %) and then decreased significantly on day 13 (~15 %; $P < 0.001$).

Interestingly, sow parity significantly modulated the use of the creep area by piglets' ($P < 0.001$), with a greater creep area use by piglets born from parity 6 and 7 sows (only 12.5 % of the sows studied): [min: 37; max: 53 %] of piglets in the creep area *vs* [min: 13; max: 26 %] for piglets born by parity 2–5 sows.

3.2.2. Piglets alone in the pen (not in contact with sow/other piglets)

Piglets were rarely observed alone in the hut (1.7–5.5 % of piglets on average) with an effect of the Season x Age interaction ($P < 0.05$, Fig. 4). During the winter, piglets were more observed alone as they grew, particularly between day 2 and day 13 ($P = 0.002$). No significant difference was measured according to the presence of a heated creep area, a pendulum or the parity of the sows.

3.2.3. Sow/piglet and piglet/piglet contacts indoors

We found more observations with at least one piglet in contact with the sow around day 2 (nearly 50 % of piglets) whatever the season (age effect, $P < 0.001$, Fig. 5). We measured a significant Season x Age effect ($P < 0.001$). Indeed, during the summer, the proportion of piglets observed in contact with the sow constantly decreased between day 2

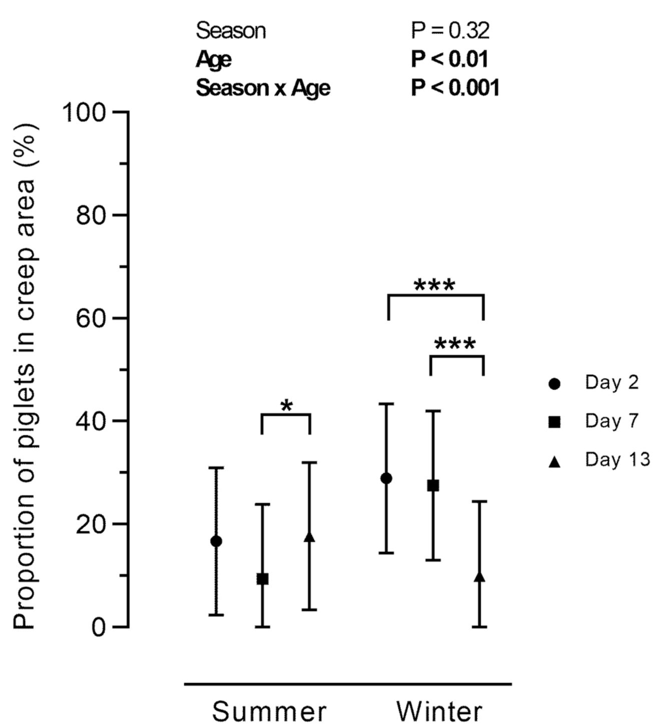

Fig. 3. Use of the creep area by the piglets. The proportions of piglets observed into the creep area are represented (emmeans +/- [IC95]) according to their age (day 2, day 7 and day 13) and to the seasons (summer and winter). Results of the post-tests are indicated: * $P < 0.05$ and *** $P < 0.001$.

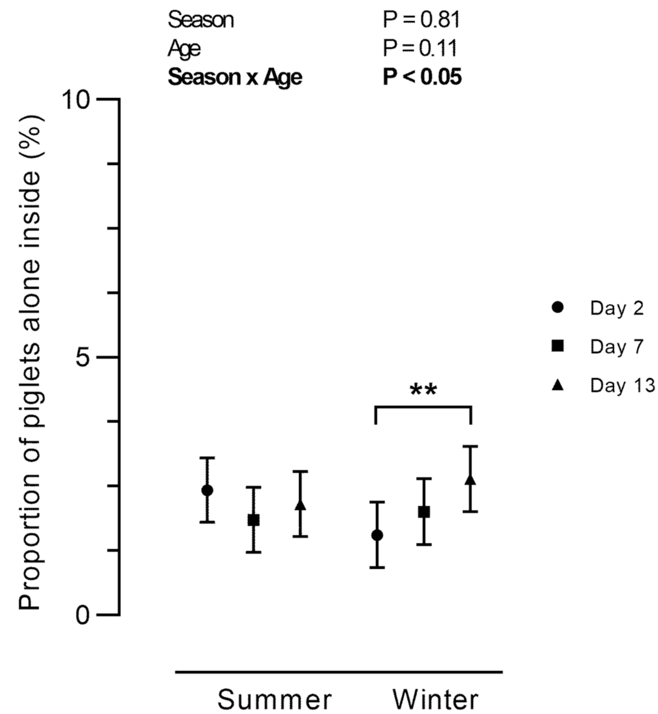

Fig. 4. Alone piglets, not in contact with conspecifics, inside the hut. The proportions of piglets observed alone inside are represented (emmeans +/- [IC95]) according to their age (day 2, day 7 and day 13) and to the seasons (summer and winter). Results of the post-tests are indicated: ** $P < 0.01$.

and day 13 ($P < 0.001$), while it did not vary between day 7 and day 13 ($P > 0.05$) during the winter. On day 13, fewer piglets were in contact with the sow in the summer than in the winter (Fig. 5A).

Also, the proportion of piglets in contact with other piglets inside the pen was not influenced by the season alone but by a significant Age x Season interaction effect ($P < 0.001$). Indeed, while the proportion of piglets in contact with other piglets increased between day 2 and day 7 in both seasons (reaching approximately 40 % of the piglets), it decreased at the later age only during the summer and continued to increase during the winter (Fig. 5B).

4. Discussion

In this study, we have shown that piglets use the indoor and outdoor space differently depending on their age, from birth to weaning, and the season (summer vs. winter). During their very first days of life, the piglets stayed more often with the sow inside the hut and more precisely in the creep area whatever the season. The following week, the piglets began to go outside. Their first exit and subsequent outings depended on their age, the temperatures and therefore the season. Piglets went out earlier when the outdoor temperatures were higher and more frequently during the summer than during the winter. In the summer, the number of piglets outside was positively correlated with the temperature. At the same time, as the piglets grew, they were less observed with the sow - which began to go out more - and more time with litter inside the hut. Nevertheless, when observed outside, they were more often seen with the sow. Finally, sows remained outside more in the summer.

In European organic farms, piglets may have access to an outdoor area from an early age, either in the form of a small closed space or of a larger grassed space. However, some farmers prefer to maintain piglets confined inside during the first days of their lives, to prevent the piglets from suffering from hypothermia (Rangstrup Christensen et al., 2018). In our study, we showed that, even if piglets were able to go outside as soon as they were born, they did not go outside until the second day of life during the summer and the sixth day after birth during the winter.

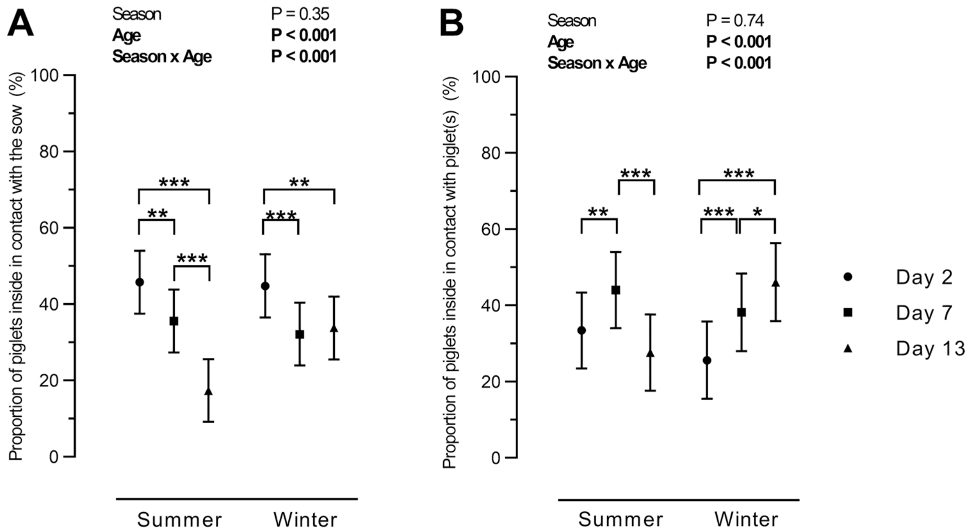

Fig. 5. Contacts between conspecifics in the hut. The proportions of piglets observed inside in contact with the sow (A) or with other piglets (B) are represented (emmeans +/- [IC95]) according to the age of piglets (day 2, day 7 and day 13) and to the seasons (summer and winter). Results of the post-tests are indicated: * $P < 0.05$, **$P < 0.01$ and *** $P < 0.001$.

Anyway, 90 % of piglets were observed inside the hut during the first few days of life, whatever the season. At this age, they are not yet able to regulate and adapt their body temperature to outside conditions. The creep area and the straw inside the hut probably played an important role in warming up the piglets. Indeed, during the first two weeks, piglets were often observed inside the creep area - 30 % of piglets were observed in winter compared to 15 % in summer - and even more during the winter and when there was a heat lamp.

The ontogeny of piglet behaviour also plays an important role in the use of the indoor and outdoor spaces. Stanged and Jensen (1991) showed that piglets born in semi-natural conditions were active only 30 % of the time for the two days following farrowing and stayed mostly in the nest or close to the sow, which stayed 90 % of the time in the nest. Social interactions between the sow and its piglets, such as nasal contacts, are the most important interactions that occur during the first five days after birth and allow them to create a bond (Jensen, 1988; Portele et al., 2019). These interactions decrease with age, which may explain why, in our study, we observed a decrease in the number of contacts between the sow and its piglets, to the benefit of an increase in the number of contacts between piglets from the second week of age, whatever the season. The increase in piglets' contacts may also have been beneficial to body temperature regulation. At the end of the first week, the piglets seemed to be more active, which is in line with Stanged & Jensen's observations (1991). They showed that piglets initially followed the sow less, before starting to follow it regularly as they moved away from the nest. This is supported by the results of our study, in that piglets went out more often with the sow (with or without conspecifics) than alone and this increased with age. This could confirm that the sow's presence outdoor may attract piglets to the outdoors particularly when they grew up, either because of social imitation, or due to the strong bond they have created with her with time, making her absence stressful (Weary et al., 1999).

Furthermore, an increase in behavioural activity from day 7, coupled with a greater ability to thermoregulate, may render piglets less sensitive to ambient temperatures. During the summer, the first time we observed piglets outside was earlier than in the winter. This is probably linked to higher temperature. This result will have to be confirmed by observing the real first exit of the piglets on continuous video samplings. Indeed, as we only observed the animals at three different ages, the real exit day may have occurred before we observed it. However, this is the first time one tries to determine the dynamic of the exit of piglets reared with outdoor access. Piglets and sows were more often seen outside in the summer than in the winter. Sows are known to spend more time outside in the summer time when shadow is provided by trees (Schild et al., 2018), which was the case in our study. This would be a way to decrease the risk of heat stress (Baert et al., 2022a). Over the two years of observations, the temperatures during summer- and winter- times were extremely different: the summertime temperatures fluctuated between 8.4°C and 26°C and, in the winter, they varied between −3.4°C and 9.5°C. We have shown a positive correlation between the outside temperatures and outdoor use for sow in winter and summer, and for piglets only in the summer. This result agrees with the limited use of the outdoor space by piglets during the winter when temperatures were below 10°C. Furthermore, sows go out more in the afternoon or the evening than in the morning. One explanation could be that sows are fed in the morning once a day, and may thus go out rather after their meal. Indeed our observations occurred before the feeding time. This is not the case for piglets, as their outdoors' use did not seem to depend on the time of day. In earlier studies, the use of an outdoor area, with shelter and shade, was shown to depend on the weather, the temperatures and the humidity (Olczak et al., 2015). In our study, humidity levels were not correlated with piglets' outings, whatever the seasons but the precipitation levels were low in both seasons. Other factors may come into play, which, when coupled with outside temperatures, humidity and precipitation levels, can influence the use of indoor and outdoor spaces by the sows and their piglets. For example, wind speed and north/south exposure, may impact on the ability of animals to regulate their body temperature and on the behaviour of piglets and their use of the pasture (Olsen et al., 2001). In our study, the hut was located on a south-facing plain, with pens not exposed equally to the prevailing west wind but all protected by swinging doors. Furthermore, the outdoor area had no shade (Schild et al., 2018). In addition, the inside temperature of the huts themselves may have modulated the use of the pasture, because it might become too warm when the external temperature is hot. Unfortunately, we don't have these data. Thus, from the present study, we are unable to determine whether other placements (e.g. more exposed to the main wind direction from the west) may have had an impact on the use of outdoors. However, wooden huts are better insulated than Metal hust for instance, providing better thermal comfort (Conrad et al., 2022).

We additionally documented that the use of the outdoor area increased with the piglets' age, both for piglets and sows. However, our study also showed that 80 % of piglets were observed indoors, except during the summer, on day 13, when they were slightly less inside, c. 70 % of piglets. Another study in Denmark reported for the following pre weaning weeks, that growing pigs housed in a barn with outdoor runs spend most of their time in a shelter (85 %), independent on the outdoor temperature (Olsen et al., 2001). Johnson et al. (2001) have reported that piglets began to spend more time outside from the age of approximately 12 days. Our results are similar to Schild et al. (2018) who showed that sows spend more time outside from 11 days after parturition compared to during the first 10 days. In our study, we did not observe the piglets after their second week of life.

Several studies have shown that an enriched environment, particularly during the farrowing phase, may have a positive impact on the exploration behaviour of pigs (e.g. Oostindjer et al., 2011). However, Cox and Cooper (2001) showed that piglets reared in either a conventional or an enriched environment, similarly increased their explorative behaviour during their first three weeks of life. Taken together these results suggest the possibility that locomotion and exploratory behaviours increase regardless of the environment during the first few weeks of life, and that piglets with increasing maturity and age become more sensitive of enrichment for the further expression of explorative behaviour. We suggest the outdoor area could become more attractive with age, particularly in terms of its diversity of fixtures, allowing extensive explorations, play activities or pigs to forage or even to eat grass. Moreover, the outdoor area could allow animals to better regulate their body temperature by using the wallow (Olsen et al., 2001). These topics on the ontogenetic effects on explorative behaviour and the enriching qualities of outdoor areas for growing piglets are relevant future study topic, as to better understand factors influencing the welfare of pigs used e.g. in the organic meat production. Furthermore, as we could only observe animals at three different period (Day2, Day 7 and Day 13) of age, it would be beneficial to develop studies with daily observations to describe the ontogeny of behaviours more precisely.

5. Conclusion

In this study, we showed that, even if piglets were able to go outside as soon as they were born, they did not seem to go outside right away. The use of the outdoor area depended on their age as well as on the outside temperatures and the season. It would be interesting to study further the factors that can stimulate piglets to stay indoors or go outside. With climate change, it is becoming increasingly important to understand the environmental parameters that can influence the use of the outdoors, and more generally, the impact this can have on the behaviour and thermal comfort of piglets. This would help farmers to increase pigs' welfare by offering suitable housing and outdoor access adapted to local conditions.

Ethical statement

This trial was set up in a Danish commercial organic farm in the Northern part of Jutland. The study was conducted according to the Danish legislation, including the legal acts on protection of pigs [Danish Ministry of Environment and Food, 2016 (Legal act on the protection of swine, no. 17 of January 07, 2016 in Danish, www.retsinformation.dk/eli/lta/2016/17)] and animal experimentation [Danish Ministry of Food, Agriculture and Fisheries, 2022 (Legal act on animal experimentation, no. 1107 of July 1, 2022, in Danish, www.retsinformation.dk/eli/accn/A20220110729)]. The study was below the permit-requiring threshold in Denmark as it did not "cause pain, suffering, anxiety, or permanent injury equal to, or greater than, that caused by the injection of a needle, done in accordance with good veterinary practice" to pigs.

CRediT authorship contribution statement

Anissa Jahoui: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jens Malmkvist:** Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Lene Juul Pedersen:** Writing – review & editing, Validation, Supervision, Funding acquisition, Conceptualization. **Blandine Lieubeau:** Writing – review & editing, Validation, Investigation, Formal analysis, Data curation, Conceptualization. **Julie Hervé:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Conceptualization. **Céline Tallet:** Writing – review & editing, Validation, Methodology, Funding acquisition, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.applanim.2024.106325.

References

Alonso, M.E., González-Montaña, J.R., Lomillos, J.M., 2020. Consumers' concerns and perceptions of farm animal welfare. Animals 10, 385. https://doi.org/10.3390/ani10030385.

Baert, S., Aube, L., Haley, D.B., Bergeron, R., Devillers, N., 2022b. To wallow or nurse: Sows housed outdoors have distinctive approaches to thermoregulation in gestation and lactation. Appl. Anim. Behav. Sci. 248, 105575 https://doi.org/10.1016/j.applanim.2022.105575.

Baert, S., Aubé, L., Haley, D.B., Bergeron, R., Devillers, N., 2022a. The protective role of wallowing against heat stress in gestating and lactating sows housed outdoors. Physiol. Behav. 254, 113898 https://doi.org/10.1016/j.physbeh.2022.113898.

Blumetto Velazco, O.R., Calvet Sanz, S., Estellés Barber, F., Villagrá García, A., 2013. Comparison of extensive and intensive pig production systems in Uruguay in terms of ethologic, physiologic and meat quality parameters. R. Bras. Zootec. 42, 521–529. https://doi.org/10.1590/S1516-35982013000700009.

Bracke, M.B., 2011. Review of wallowing in pigs: description of the behaviour and its motivational basis. Appl. Anim. Behav. Sci. 132 (1-2), 1–13. https://doi.org/10.1016/j.applanim.2011.01.002.

Bushby, E.V., Dye, L., Collins, L.M., 2021. Is magnesium supplementation an effective nutritional method to reduce stress in domestic pigs? A systematic review. Front. Vet. Sci. 7, 596205 https://doi.org/10.3389/fvets.2020.596205.

Conrad, L., Aubé, L., Heuchan, E., Conte, S., Bergeron, R., Devillers, N., 2022. Effects of farrowing hut design on maternal and thermoregulatory behaviour in outdoor housed sows and piglets. Appl. Anim. Behav. Sci. 251, 105616 https://doi.org/10.1016/j.applanim.2022.105616.

Cox, L.N., Cooper, J.J., 2001. Observations on the pre-and post-weaning behaviour of piglets reared in commercial indoor and outdoor environments. Anim. Sci. 72 (1), 75–86. https://doi.org/10.1017/S1357729800055570.

Delanoue, E., Dockes, A.-C., Chouteau, A., Roguet, C., Philibert, A., 2018. Regards croisés entre éleveurs et citoyens français: vision des citoyens sur l'élevage et point de vue des éleveurs sur leur perception par la société. INRA Prod. Anim. 31, 51–68. https://doi.org/10.20870/productions-animales.2018.31.1.2203.

Delsart, M., Pol, F., Dufour, B., Rose, N., Fablet, C., 2020. Pig Farming in alternative systems: strengths and challenges in terms of animal welfare, biosecurity, animal health and pork safety. Agriculture 10, 261. https://doi.org/10.3390/agriculture10070261.

Herpin, P., 1989. Bases métaboliques et physiologiques de l'acclimatation du porcelet au froid. Prod. Anim. 2 (4), 255–265 https://hal.science/hal-00895873.

Herpin, P., Damon, M., Le Dividich, J., 2002. Development of thermoregulation and neonatal survival in pigs. Livest. Prod. Sci. 78, 25–45. https://doi.org/10.1016/S0301-6226(02)00183-5.
Hrupka, B.J., Leibbrandt, V.D., Crenshaw, T.D., Benevenga, N.J., 2000. The effect of thermal environment and age on neonatal pig behavior. J. Anim. Sci. 78, 583. https://doi.org/10.2527/2000.783583x.
Jensen, P., 1988. Maternal behaviour and mother—Young interactions during lactation in free-ranging domestic pigs. Appl. Anim. Behav. Sci. 20, 297–308. https://doi.org/10.1016/0168-1591(88)90054-8.
Johnson, A.K., Morrow-Tesch, J.L., McGlone, J.J., 2001. Behavior and performance of lactating sows and piglets reared indoors or outdoors. J. Anim. Sci. 79, 2571. https://doi.org/10.2527/2001.79102571x.
Lau, Y.Y.W., Pluske, J.R., Fleming, P.A., 2015. Does the environmental background (intensive v. outdoor systems) influence the behaviour of piglets at weaning? Animal 9, 1361–1372. https://doi.org/10.1017/S1751731115000531.
Leeb, C., Rudolph, G., Bochicchio, D., Edwards, S., Früh, B., Holinger, M., Holmes, D., Illmann, G., Knop, D., Prunier, A., Rousing, T., Winckler, C., Dippel, S., 2019. Effects of three husbandry systems on health, welfare and productivity of organic pigs. Animal 13, 2025–2033. https://doi.org/10.1017/S1751731119000041.
Malmkvist, J., Pedersen, L.J., Damgaard, B.M., Thodberg, K., Jørgensen, E., Labouriau, R., 2006. Does floor heating around parturition affect the vitality of piglets born to loose housed sows? Appl. Anim. Behav. Sci. 99, 88–105. https://doi.org/10.1016/j.applanim.2005.10.007.
Mayorga, E.J., Renaudeau, D., Ramirez, B.C., Ross, J.W., Baumgard, L.H., 2019. Heat stress adaptations in pigs. Anim. Front. 9, 54–61. https://doi.org/10.1093/af/vfy035.
Nakamura, K., Tanaka, T., Nishida, K., Uetake, K., 2011. Behavioral indexes of piglet welfare: comparison of indoor and outdoor housing systems: behavioral indexes for welfare of pigs. Anim. Sci. J. 82, 161–168. https://doi.org/10.1111/j.1740-0929.2010.00806.x.
Olczak, K., Nowicki, J., Klocek, C., 2015. Pig behaviour in relation to weather conditions–a review. Ann. Anim. Sci. 15 (3), 601–610. https://doi.org/10.1515/aoas-2015-0024.
Olsen, A.W., Dybkjær, L., Simonsen, H.B., 2001. Behaviour of growing pigs kept in pens with outdoor runs II. Temperature regulatory behaviour, comfort behaviour and dunging preferences. Livest. Prod. Sci. https://doi.org/10.1016/S0301-6226(01)00173-7.
Oostindjer, M., Van Den Brand, H., Kemp, B., Bolhuis, J.E., 2011. Effects of environmental enrichment and loose housing of lactating sows on piglet behaviour before and after weaning. Appl. Anim. Behav. Sci. 134, 31–41. https://doi.org/10.1016/j.applanim.2011.06.011.
Pedersen, L.J., Malmkvist, J., Jørgensen, E., 2007. The use of a heated floor area by sows and piglets in farrowing pens. Appl. Anim. Behav. Sci. 103, 1–11. https://doi.org/10.1016/j.applanim.2006.03.015.
Pedersen, L.J., Malmkvist, J., Kammersgaard, T., Jørgensen, E., 2013. Avoiding hypothermia in neonatal pigs: effect of duration of floor heating at different room temperatures1. J. Anim. Sci. 91, 425–432. https://doi.org/10.2527/jas.2011-4534.
Portele, Scheck, Siegmann, Feitsch, Maschat, Rault, Camerlink, 2019. Sow-piglet nose contacts in free-farrowing pens. Animals 9, 513. https://doi.org/10.3390/ani9080513.
Prunier, A., Lubac, S., Mejer, H., Roepstorff, A., Edwards, S., 2014. Health, welfare and production problems in organic suckling piglets. Org. Agr. 4, 107–121. https://doi.org/10.1007/s13165-013-0052-0.
Rangstrup-Christensen, L., Krogh, M.A., Pedersen, L.J., Sørensen, J.T., 2018. Sow level risk factors for early piglet mortality and crushing in organic outdoor production. Animal 12, 810–818. https://doi.org/10.1017/S1751731117002178.
Renaudeau, D., Dourmad, J.Y., 2022. Review: future consequences of climate change for european union pig production. animal 16, 100372. https://doi.org/10.1016/j.animal.2021.100372.
Renaudeau, D., Gourdine, J.L., St-Pierre, N.R., 2011. A meta-analysis of the effects of high ambient temperature on growth performance of growing-finishing pigs. J. Anim. Sci. 89, 2220–2230. https://doi.org/10.2527/jas.2010-3329.
Schild, S.L.A., Baxter, E.M., Pedersen, L.J., 2020. A review of neonatal mortality in outdoor organic production and possibilities to increase piglet survival. Appl. Anim. Behav. Sci. 231, 105088 https://doi.org/10.1016/j.applanim.2020.105088.
Schild, S.L.A., Rangstrup-Christensen, L., Bonde, M., Pedersen, L.J., 2018. The use of a shaded area during farrowing and lactation in sows kept outdoors. Appl. Anim. Behav. Sci. 209, 22–29. https://doi.org/10.1016/j.applanim.2018.08.019.
Stanged, G., Jensen, P., 1991. Behaviour of semi-naturally kept sows and piglets (except suckling) during 10 days postpartum. Appl. Anim. Behav. Sci. 31, 211–227. https://doi.org/10.1016/0168-1591(91)90006-J.
Titterington, R.W., Fraser, D., 1975. The lying behaviour of sows and piglets during early lactation in relation to the position of the creep heater. Appl. Anim. Ethol. 2, 47–53. https://doi.org/10.1016/0304-3762(75)90064-4:.
Weary, D.M., Appleby, M.C., Fraser, D., 1999. Responses of piglets to early separation from the sow. Appl. Anim. Behav. Sci. 63 (4), 289–300. https://doi.org/10.1016/S0168-1591(99)00021-0.