EFFECTS OF ENVIRONMENTAL TEMPERATURE ON FOOD INTAKE IN GROWING PIGS

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(Received 3 July 1973)

Abstract—1. The food intake of forty-seven young growing pigs has been measured during exposure to cold, thermoneutral and warm ambient temperatures. In some experiments the pigs were allowed to feed from an open bowl and in others they performed an operant response to obtain food.

2. When the pigs were housed at a thermoneutral temperature and transferred once a day to a high or low temperature before feeding, food intake was not affected. When the same pigs had to make an operant response for food they ate less in the hot environment.

3. Pigs kept at 20°C and fed once a day by operant conditioning at 5, 20 or 35°C ate less at 35°C than at 20°C, but there was no difference in intake between 5 and 20°C. If pigs were exposed for 2 or 4 hr to 5, 20 or 35°C before they were fed, then food intake in the cold environment increased, but the decrease in food intake in the hot environment was less apparent.

4. Measurement of food intake over 24 hr periods at various temperatures revealed a circadian rhythm with maximum intake diurnally. Changing the ambient temperature from thermoneutral to warm was accompanied by a transitory decrease in food intake; changing from thermoneutral to cold was accompanied by a sustained rise in intake.

INTRODUCTION

The control of food intake depends on many factors (Teitelbaum, 1967) one of which is the environmental temperature to which the animal is exposed (Hamilton, 1967). A wide variety of species ranging from rats and rabbits to large animals have been studied and in each case it has been possible to demonstrate that animals eat more in a cold environment than a warm one (Gasnier & Mayer, 1939; Kleiber, 1961; Hamilton, 1963, 1964).

Brobeck (1948) suggested that the rise in deep body temperature, which begins immediately on feeding, tends to inhibit further food intake, and that when this is combined with an elevated temperature consequent on exposure to a hot environment, the amount of food eaten declines. Evidence which supports this idea derives from the studies of Andersson & Larsson (1961) who demonstrated that when the hypothalamus of the goat was heated locally food intake declined, while cooling increased it. In contrast, Spector et al. (1968) working with rats, and Ingram (1968) using the pig found that heating the hypothalamus led to an increase
in food intake and cooling to a decrease. In any event the changes in core temperature which occur when the ambient temperature falls sometimes involve an increase provided the cold is not too severe (Ingram & Legge, 1970).

Alternative mechanisms which might control the change in food intake in response to alterations of ambient temperature could involve skin temperature, mean body temperature, metabolic rate or the endocrine glands. The different mechanisms would not all require the same times to operate and in the present study the time course of changes in food intake after a change in ambient temperature have been investigated in order to determine whether any of these possibilities can be eliminated. Two methods of presenting the food have been employed because, as Miller (1968) has pointed out, there are sometimes differences in the quantity of food eaten when it is freely available and when the animal has first to perform some task.

MATERIALS AND METHODS

Animals

Forty-seven growing pigs (Sus scrofa females and castrated males) of the Large White breed aged 6–12 weeks and weighing between 12 and 20 kg were used. The animals were obtained from the Institute farm shortly after weaning.

Management

The animals were housed in individual cages in rooms, the temperature of which could be controlled to within ±1°C, and provided with water ad lib. Feeding arrangements differed between individual experiments, but on days when the animals were not being used in an experiment they were fed 4.5 per cent of their body weight in the form of a pelleted food once a day. This level of feeding corresponds to that generally used under husbandry conditions.

Measurements of food intake

In some experiments the animal was fed from an open bowl and allowed to eat for 2 hr. The amount of food eaten was then measured by weighing the remaining pellets, including any which had been upset onto the floor of the cage. This latter point is not unimportant since some pigs display a tendency to play with the food once they have had enough.

In other experiments the pig obtained food by means of an operant response which consisted of pushing against a switch panel with the snout. This action operated a device which delivered 1.5 g of food into a bowl. Before such experiments the pigs were exposed under the experimental conditions and trained to the point at which 300–800 g of food were being obtained in 2 hr. During an experiment the animals were again allowed to feed for 2 hr, at the end of which time some pigs pressed the switch but no longer ate the food which was delivered; at high temperatures some animals went to sleep. The food intake was corrected for the quantity of any uneaten pellets. In this type of feeding the number of responses (presses on the panel) which had to be made for one reinforcement (delivery of food) were in the ratios 1:1, 5:1 or 10:1.

In studies involving food intake over consecutive 24-hr periods similar techniques were used. A large bowl of food was used in studies which involved non-operant feeding and the amount eaten measured every 24 hr. In experiments using an operant response, the number of reinforcements obtained every 15 min was recorded on a data logger over the 24-hr period.
FOOD INTAKE IN PIGS

Experimental

In those studies in which the pigs were fed once a day at different ambient temperatures, the animals were fed at the control thermoneutral ambient temperature between the days on which they were fed at 5 or 35°C. The sequence in which the hot and cold ambient temperatures were presented was random. In order to ensure that the results were not affected by a break in the routine at weekends the pigs were given a further training session in the experimental situation on the first day of the week at the control temperature and the experiments started the next day.

Analysis of results

Standard statistical procedures involving the paired t-test and the split-plot analysis of variance were used.

RESULTS

Effect of a short exposure to hot or cold environmental temperatures on food intake

The thirteen pigs used in this experiment were housed singly at 20°C and supplied with water ad lib. but no food. Once a day the pigs were brought into the laboratory and placed in a temperature-controlled room at 5 or 35°C. On some days the pigs were fed from an open bowl and on others they performed an operant response for food using a response : reinforcement ratio of 1 : 1. The order in which the temperatures and type of feeding were presented was at random. At the end of 2 hr the rate of feeding had declined considerably and the pigs sometimes appeared to be playing with the food pellets rather than eating them. The mean amounts of food actually eaten in the 2-hr period are presented in Table 1.

<p>| Table 1—Amount of food eaten in 2 hr at different ambient temperatures and conditions of food presentation |
|---------------------------------------------------|---------------------------------------------------|
| Food presentation                                      |</p>
<table>
<thead>
<tr>
<th>Open bowl</th>
<th>Operant response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature (°C)</td>
<td>5</td>
</tr>
<tr>
<td>Food eaten (g) (mean ± S.E.M.)</td>
<td>859 ± 51</td>
</tr>
</tbody>
</table>

During the remaining 22 hr each day the pigs were housed individually at 20°C and allowed water but no food.

Comparison of the amount of food eaten at 5 and 35°C from an open bowl by means of a paired t-test revealed no statistically significant difference (P = 0.6–0.5). When the animals had to make an operant response to obtain food the probability that the difference in the quantity obtained at 5 and 35°C was due to chance was P.05–02.

Effects of various short-term exposures to hot or cold environments on food intake compared with the amount eaten in a thermoneutral environment

In these experiments a further twenty-three pigs learned to obtain food by making an operant response for food using a response : reinforcement ratio of
As in the previous experiment the animals were housed singly at 20°C and provided with water ad lib. but no food. On the first day of the week they were fed at 20°C as a final training session and on the next three days they were fed at 5, 20 or 35°C. In the first experiment pigs were allowed to feed as soon as they were introduced into the room, but in the next two experiments different pigs were first held in the room in another cage for 2 or 4 hr before being placed in the cage with the feeding apparatus. The results of this study are presented in Table 2 and have been analysed by the analysis of variance applicable to experiments involving a split plot design. This analysis revealed that the overall effects of feeding at different temperatures, and the interaction of the effects of temperature and of different delay times before feeding are statistically significant at the 0.05 per cent level. Examination of the mean values for each experiment in Table 2 suggests that the amount of food eaten after a delay in the room tends to be greater than that which the pigs ate when they were fed immediately on entry. The increase was much more marked, however, when the animals were exposed to 5°C than at other temperatures. The analysis of variance of individual experiments revealed that while the difference in food intake at 5 and 20°C was not significantly different statistically when the pigs were fed immediately on entry into the room, it was significantly different when there was a delay of 4 hr \( (P < 0.01) \). On the other hand, the decline in food intake at 35°C compared with 20°C tended to become smaller if feeding was delayed, and it was no longer statistically significant after 4 hr delay.

**Food intake measured over 24-hr periods at various environmental temperatures**

Four pigs were housed at 10, 25 or 35°C and fed ad lib. from an open bowl. When the animals were exposed for 24 hr to 25 and 10°C on alternate days, food intake was always greater at the lower temperature, while changes between 25 and 35°C led to a decrease in food intake at the higher temperature (Fig. 1). Keeping the room temperature at 25°C for 6 days and then changing it to 10°C for 6 days

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**Table 2—Amount eaten (g ± S.E.M.) in 2 hr by pigs performing an operant response for food at different temperatures and after different lengths of exposure to the given temperature before being allowed to feed**

<table>
<thead>
<tr>
<th>Length of exposure (hr) before feeding</th>
<th>Ambient temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>0</td>
<td>673 ± 36</td>
</tr>
<tr>
<td>2</td>
<td>904 ± 52</td>
</tr>
<tr>
<td>4</td>
<td>925 ± 96</td>
</tr>
</tbody>
</table>

During the rest of the day the animals were housed individually at 20°C and allowed water but no food.
led to a sustained increase in food intake at the lower temperature. Changing from 25 to 35°C led first to a decrease in the amount of food eaten on the first day after the change, but the food intake tended to return to the control value on subsequent days (Fig. 2).

In the next study seven pigs performed an operant response for food using a response : reinforcement ratio of 5 : 1 or 10 : 1. In experiments involving alternate days at 35 and 10°C food intake varied inversely with temperatures as in the previous experiment. If the duration of the exposure to a given ambient temperature was longer than a day, however, the effect on food intake was less obvious. As in the previous study, on initial exposure to heat there was a marked decrease in food intake but after a few hours, feeding was resumed.

Food intake in these experiments was recorded every 15 min, and the 6 hr moving averages were computed and plotted at 15-min intervals. The results of one experiment are presented in Fig. 3 and a circadian rhythm in activity associated with feeding can be seen. When the temperature was changed from 25 to 10°C on alternate days the heat appeared to depress food intake and cold to stimulate it, but in addition there was also a decline in feeding for a few hours beginning at about midnight. In an experiment of 3 days at 20°C followed by 4 days at 35°C and another 3 days at 20°C, the amount of food eaten tended to increase as the animal grew but the period at 35°C checked this increase.
FIG. 2. Daily food intake of pigs fed ad lib. from an open bowl. One pig was subjected to alternative days at 25°C (open) and 10°C (hatched), and the other to 25°C (open) and 35°C (black).

FIG. 3. Results obtained from a pig which obtained food by making an operant response (ratio 10 : 1). The food intake during 30 min is indicated by histograms (left scale) and the 6 hr moving average is indicated by the continuous line (right scale). On alternate days the temperature was at 10 and 35°C. The black bar indicates the lower temperature.

DISCUSSION

The results of the present study demonstrate that when the pig has to make an operant response for food it eats more in a cold environment than in a warm one, even if the exposure is limited to the length of the meal. When the quantity of food eaten in an environment close to thermal neutrality was compared with that
eaten in a hot or cold environment, however, it appeared that the immediate response to a change in ambient temperature was limited to the effects of heat. In contrast the increase in food intake in an ambient temperature of 5°C compared with 20°C developed over 4 hr while the effects of a hot environment diminished over the same period. These findings suggest that at least two mechanisms may be involved in the pig's response to a change in ambient temperature which affects its food intake.

It is known from other studies (Ingram, 1964) that when 6-12-week-old pigs are exposed to 35°C, rectal temperature increases gradually from 39°C to a mean value of 40.6°C and respiratory frequency from 20/min to a mean of 181/min. The possibility thus arises that food intake is inhibited chiefly over the period during which a new thermal equilibrium is being established. The act of eating would disturb the equilibrium even further due to the rise in body temperature which begins immediately on eating (Ingram & Legge, 1970). Also, in animals which pant, evaporative heat loss from the buccal cavity is reduced to near zero while the animal is eating (Ingram & Whittow, 1962). The present experiments in which pigs were fed ad lib. for several days indicate that although food intake changed each day when the ambient temperature was altered daily, there was at least a partial recovery in food intake when the pigs were kept at 35°C for several days. These animals had continuous access to food and so were not strictly comparable to the first series of experiments. Nevertheless, readings taken every 15 min revealed an initial fall in food intake over the first few hours after the change in temperature. A fall in food intake, with subsequent partial recovery, has also been observed in the rat (Hamilton, 1963), but in this species food intake in a hot environment reached a stable level well below that in the control environment. The rats, however, were adult, while the pigs in the present study were growing and in environments close to or below thermal neutrality food intake increased daily. The steady rate of food intake in a hot environment observed in the present experiments may therefore represent a virtual decline. Morrison & Mount (1971) observed a sustained fall in food intake in a group of pigs when the temperature was changed from 22 to 33°C but their animals were larger and the daily increase in food intake would therefore not have been as great as in the present series. In the very hot environment of 40°C used by Heitman & Hughes (1949) food intake was much reduced, but the pigs were probably close to the upper limit of temperature which they could endure.

The increase in the quantity of food eaten when the pig was kept at 5°C for 4 hr does not appear to have been related simply to changes in skin temperature. Ingram (1964) found that skin temperatures had reached a new level 1 hr after the environmental temperature was changed, and any effects related to changes in peripheral temperatures might therefore have been expected to be manifest during the 2-hr period of the meal. Similarly, changes in metabolic rate in response to a change in temperature are known to occur within an hour of the conditions being changed. Studies of pigs over several days revealed no tendency for there to be an initial overshoot in food intake, but once the increase had occurred, daily
intake continued to increase steadily with time. An examination of the records taken every 15 min over the period of change in ambient temperature indicates that the increase in the quantity eaten began a few hours after the temperature had fallen. One possibility is that the thyroid hormone is involved, and the work of Donhoffer & Vonotzky (1947a, b) who injected mice with thyroxine and observed an increase in food intake supports this idea. As pointed out by Hamilton (1967), however, this cannot be the only factor involved because thyroidectomized animals also increase their food intake in the cold.

Acknowledgement—We wish to thank Mr. D. E. Walters of the A.R.C. Statistics Unit for his help and advice.

REFERENCES


*Key Word Index*—Pigs; temperature; food; rhythms.