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INTENSIVE HOUSING AND ITS EFFECTS ON FARM ANIMALS

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Intensive animal production is not a new idea. It is true that historically the rearing of domestic animals for food has been an extensive rather than an intensive practice but this is a generalisation. Whenever, and wherever a population has grown fast enough, large enough and affluent enough, intensive animal production has developed simultaneously to satisfy the demand for meat. For example circa 37 BC the *pastio villatica* bred edible snails and fieldfares or reared dormice in jars to satisfy Rome's growing demand for luxury items for the epicures' tables (White, 1970). In the late 18th century, large scale fattening of pigs and cattle fed on distillers' wash and housed in close confinement in sophisticated buildings provided meat for the hungry masses of the rapidly expanding metropolis of London (Middleton, 1798).

Today intensive animal production is characterised by an increase in capital investment per animal in housing and equipment, a reduction in labour usage per animal, an increase in the nutrient intake per animal to achieve a high rate of output, and a standardisation of the final product (Blaxter, 1967). Intensive animal production units tend to be larger and more concentrated in their use of land than traditional farm enterprises and it has been suggested (Cunha, 1967) that they demand a higher level of ability, management skill and technical knowledge. This may well be so, for the measure of their success is an economic one and this is often the only criteria on which they are judged (Junge 1967). As a result, at any time, the economic situation will dictate that intensive animal production units must continually strive to maximise the overall efficiency with which they convert the basic resources of feed, labour and capital into saleable products.

Intensive housing is only a part of intensive animal production yet its development tends to reflect the continuous struggle to reduce the costs of production by reducing investment and improving working conditions inside the building. Simultaneously, housing must continue to aid the improvement of biological performance by creating an environment conducive to optimal conversion of feed into meat. The dramatic increase in building costs over the last few years from approximately 10% in 1970 to almost 25% in 1974, has resulted in a greater effort to reduce capital expenditure generally by concentrating on either or both of the following factors:

1. Development and use of cheaper materials and building methods.
2. Design of buildings where more efficient use is made of enclosed space.

In the former case where a structure must be of high standard to produce a quality environment for the intensive rearing of pigs, for example, maximum savings are only likely to be in the region of 8–10%. It is in the latter case, the more efficient use of space, that significant advances have been made, and in the last 20 years the stocking density for beef cattle has increased five-fold, and the use of multi-bird, multi-tiered cages for laying hens has, compared with deep litter systems, increased the stocking density sixteenfold (Sainsbury 1967). The other major factor in intensive livestock production, the reduction in labour usage per animal, has also undergone dramatic changes in the last decade. The continued reduction in availability of farm labour, particularly of the quality necessary for the working and management of intensive units, together with the increase in wages and the demand for improved working conditions, has resulted in a concentrated effort to reduce unproductive and menial tasks to a minimum. Here, the mechanisation of feed transportation and delivery and the removal of wastes has received most attention. In the latter instance the reduction or elimination of litter (mainly straw) has been a feature of intensive livestock production systems and this, together with the development of systems of high stocking density, forms the main theme for the remainder of this paper.

The development of systems aimed at the elimination of litter

Traditionally all farm livestock were bedded on litter, usually oat, barley or wheat straw although other materials such as wood shavings, sawdust, peat moss, sand etc. have been used. The resultant manure was then returned to the land as an organic fertiliser so completing the plant-animal-plant cycle. In many instances, livestock were kept solely to produce manure for the benefit of the arable enterprises on the farm and indeed one of the primary reasons for the development of enclosed housing for cattle was the preservation of the quality of the manure (Moscrop, 1865, 1890). This reason for promoting enclosed housing or for the conservation of manure has of recent years seemed much less significant with the development of artificial fertilisers although the present world shortage of inorganic fertilisers may again revive interest in the use of organic wastes. Currently a fully enclosed loose housing system for cattle would require up to 15 kg straw per head per day for dairy cows or mature fat cattle and the littering operations would account for one-third of the stockman's time (Sturrock 1960).

Similarly, in fattening pig enterprises, out of a total of 14,6 min/head week the stockman may well spend 4,8 min on cleaning and littering (Sturrock, 1960). Many factors such as the vagaries of season and weather and the use of short strawed cereal varieties, now produce a straw of variable quality at widely fluctuating prices.

Consequently housing systems have been developed where the use of straw is reduced or even eliminated entirely. The introduction of building designs which discriminated between lying and feeding areas for example reduced the demand for litter by 50% and eventually the innovation of the cow cubicle circa 1960 (Evans, 1964) reduced the litter required to a modest 1/2 kg sawdust per head per day (Soutar, 1964a). With beef cattle and pigs the re-introduction of slatted floors circa 1950 (Norbø 1955) has eliminated the need for any bedding at all in some systems. It should be appreciated, of course, that these changes took place gradually; the amount of litter being used in any one housing system would be reduced until the system ceased to function effectively and then a new development would occur based on a new concept and so the development would continue until eventually a system was created which required no litter.

The problems associated with the elimination of litter

Apart from its contribution as an organic fertiliser, straw bedding performs a variety of useful functions. It has the capacity to absorb almost twice its weight of liquid and therefore when used in adequate quantities it provides a soft dry lying area. By placing a shock absorbent layer of straw between the animal and the floor, foot and leg lesions, teat damage etc. can be reduced and the incidence of secondary infections can be minimised. On the other hand, inadequate quantities of straw which are continually saturated and which merely accumulate as a wet, rotting mass can be harmful and predispose livestock to foot rot. The ingestion of straw creates no problems, and under certain circumstances its presence may help to promote a stable social environment by contributing to the play behaviour of young stock or by acting as a stress ameliorating factor to animals under social or environmental strain (Van Putten, 1969).

The paramount advantage of straw is its use, in practice, to ameliorate adverse climatic environments resulting from sub-optimal housing or management (Baxter, 1971a). When spread as a thin layer (approximately 25 mm deep) over the floor it reduces the conductive heat loss of the recumbent animal, thus reducing the need for floor insulation, and, when loosely spread to a depth of 150–300 mm, it can provide total cover for animals such as pigs and effectively reduce the cooling effects of adverse air currents. To quantify thermal environmental value of straw is however difficult. Moustgaard, Nielsen & Sorensen (1959) have shown for example that pigs on a good straw bed at 2,8°C had a similar food conversion efficiency to pigs without bedding at 7,8°C. Under such adverse conditions, where the ambient temperature is below the critical temperature of the pigs, the thermal advantage of straw would be maximised. Nevertheless, at this temperature level, straw would appear to have an equivalent temperature compensating value of approximately 5°C.

More recently Verstegen & Van der Hel (1974) have reported that the effective critical temperature of pigs weighing 40 kg was 11,5 to 13,0°C on straw bedding, 14 to 15°C on the same solid floor without bedding and 19 to 20°C on concrete slats. Although the lowest ambient temperature operated in their experiments was only 5,4°C for pigs with straw and 8°C without straw or on concrete slats, it would appear that for the young pig the concrete slatted floor produces a particularly adverse thermal environment whilst the benefit of straw on the solid floor is only worth approximately 2°C. It is surprising that such differences in the effective critical temperature should accrue when there were no significant differences in the extra thermoregulatory heat production for all three floor treatments below the effective critical temperature. Perhaps the small difference between the strawed asphalt floor and the unstrawed floor is due to the low thermal conductivity of the asphalt although no values are quoted and the particularly adverse results of the slatted floor may be due in part to the extra convective heat losses which could have occurred with an air movement around the slats of 0,1 – 0,15 m/s especially at the lower air temperatures. Under such conditions, 20–40 kg pigs would be considered uncomfortable (Sainsbury, 1954) and as such the environmental demand could be about 125% of the metabolic heat production of the pig in the comfort zone (Smith, 1964) which of course may or may not be synonymous with the zone of thermal neutrality.

With the new born pig thermal conditions are even more critical and straw is likely to be even more highly rated. Mount (1967) has shown that a 25 mm layer of straw placed over a concrete floor can reduce the young pigs conductive heat loss when lying by approximately 60% and is the equivalent of raising the floor temperature by 15°C. Total immersion in straw could in addition decrease both the radiative and convective heat transfer thereby further reducing total heat loss (Mount, 1966; Bond, Heitman & Kelly, 1965).

In hot environments, straw bedding, except when kept wet, could constitute a thermal burden so increasing the animals efforts to maintain homeostasis. Under such conditions, cool floors are likely to be advantageous in ameliorating the effects of temperature (Bond, Heitman & Kelly, 1964).

The development of systems aimed at increasing the efficiency of space utilisation

The development of housing systems which featured a reduction in service space e.g. feed passages etc. and promoted the increase in animal stocking densities occurred simultaneously with the attempt to devise litter free systems culminating, as previously described, in the slatted floor system. Where the slatted floor was unsuccessful, e.g. for dairy cows, the cubicle has become the most popular form of animal accommodation.

Improving the efficiency of space utilisation can be achieved by eliminating unnecessary excess such as over-wide feed passages or surplus storage space or by utilising the same space for two or more activities, e.g. feeding in the parlour or using passage space as collecting pens. In the NE of Scotland for example the feeding of roughage to dairy cows in the cubicle has eliminated the need for additional areas of concrete (Baxter, 1971b) and the design of overhead feed passages in piggeries has made use of vertical rather than horizontal space. Although, as a result of rudimentary behavioural observations, the design of housing systems with separate activity areas i.e. lying, feeding and defecating, has led to a reduction in the use of straw, some of these systems, particularly for pigs, have resulted in an increase in areas of unusable space, i.e. areas adjoining walls and in corners (Livingston & Robertson, 1967). The development of the slatted floor has once again allowed for maximum space economies by maximising total free space and fully slatted floor layouts for pigs have been shown to require 13% less total building space per pig than solid floor layouts (Lileng, 1959). A similar study by Soutar (1964b) but also taking into consideration different feeding methods, i.e. manual, mechanical and hydraulic feeding, indicated that with all methods of feeding except floor feeding, the fully slatted floor layout requires the least total building area per pig. Comparisons of part slatted and fully slatted layouts have shown that savings in total building space as high as 11% can be achieved although cost per unit area may also increase. However, apart from the reduction in waste space or the development of new hardware technology (i.e. slats) the most significant development has been the gradual reduction in space per animal (increased stocking density). It is in this particular area of development that the greatest space savings have been made and where the greatest problems have occurred and it is this aspect which requires further elaboration.

The problems associated with increased stocking density

Stocking density or stocking rate is determined from a knowledge of the number of animals confined to a particular area and the available area to which the members of the group are allowed access.

Stocking density can be altered by changing the number of animals on a given area or by changing the amount of space available but although the two methods give the same numerical answer the problems seen from an ethological viewpoint may be quite different. Although the housing of livestock in more confined conditions increases the risks of disease transmission, adds to the potential risk of external trauma and alters the pattern of energy transfer between animal and environment, the greatest source of change is in the social environment. This is defined as those conditions within the immediate surroundings of an individual which result from the presence of other individuals of the same or some other species. The social environment may be influenced by the qualities of the individuals, e.g. species, breed, sex, etc., and the qualities of the environment, e.g. availability of shelter, population density, or availability of food supply. In the majority of livestock enterprises groups of animals usually comprise simple mono-caste societies of relatively small numbers although when compared with the more complex multi-caste societies of breeding animals the response to crowding would appear to be similar. Increases in population density tend to lead to increases in social interactions and in particular behavioural aberrations and agonistic interactions. As aggression between conspecifics is not only relatively common but appears to be fundamental to survival value, e.g. the assertion of the individual when competing for limited resources – food, space, mating partners – agonistic interactions resulting from aggression could be expected to increase as the competition for space increased. Suppression of aggression though not necessarily of all agonistic interactions would appear to be one of the advantages of organisational structures such as territory rituals or dominance hierarchies. Agonistic behaviour of an individual may be influenced by external or internal effects. The internal effects of genetic and psychological factors are likely to affect the level and rate of stimulation that is required to produce agonistic behaviour.

Bryant (1970) has suggested that the external environment may modify agonistic behaviour by modifying the occurrence of aggressive stimulus situations or by manipulating the perceptual threshold of the individual to the aggressive stimulus situation. Groups of pregnant gilts for example when provided with inadequate trough space will display increased amounts of aggression (Rasmussen, Banks, Berry & Becker, 1962). It would appear that in a situation where space is at a premium agonistic interactions may be further exacerbated by the additive effect of other environmental stimuli. Scott (1958) for example suggests that the result of accumulating a number of weak stimuli is to elicit a response similar to that associated with a single stronger stimulus. As a result, animals in an already stressed condition such as might occur with high population density may have their aggressive behaviour modified by changes in temperature; a sudden depression in temperature may stimulate aggressive tendencies whilst elevated temperatures may produce changes of an opposite nature. Van Putten (1969) was unable to stimulate tail biting in pigs until air temperatures were lowered from 28 to 23°C.

It is evident therefore that social stress can originate from a variety of stimuli, that various stimuli may be additive in their effects and some may carry more social weight than others and that the resultant of these stimuli may be manifested in the quantity and quality of agonistic interactions. It may also be true however that alterations in the quality and number of agonistic responses may well represent a form of adaptation to social stress. Social organisation may reduce fighting amongst groups of animals but individuals at the bottom of the social scale may themselves be under social stresses related to their rank, especially in competitive or frustrating situations (Guhl, 1964). Guhl (1953) has reported that high ranking birds have precedence at the food trough, the nest, the roost and the dusting areas. They also have a greater freedom of movement about the pen. It has also been suggested by Bryant (1968) that tail biting in pigs is a mal-adaptive behavioural pattern associated with low ranking individuals.

There is now little doubt that from whatever stimuli the behavioural responses are elicited that stocking density has a stress effect which can be measured in terms of physiological adaption, behavioural alterations and economic performance. Increased population density in chickens of 20–24 weeks of age (Siegel, 1959a), in cockerels up to 17 weeks of age (Siegel, 1960) and in adult laying stock (Siegel, 1959b) have all resulted in adrenal hypertrophy. The incidence of gastric ulceration, a phenomenon believed to be associated with the General Adaptive Syndrome (Selye, 1956) has also been correlated with the increase in intensive husbandry systems for pigs (Kowalczyk, 1969). Many other factors are also believed to be associated with this phenomenon and as yet it is not clear whether over-crowding increases the incidence of ulceration or merely its severity.

In terms of agonistic interactions, Bryant and Ewbank (1972) have reported that in a comparison of ration-fed pigs housed in groups of 6, 12 or 18 at either 0,94 m^2 or 0,56 m^2/pig the smallest group of pigs at the larger space allowance had the least agonists encounters although the intensity of aggression appeared to be worse. Habituation to social relationships and the area available for manoeuvring are believed to be confounding factors. Space for manoeuvring has also been implicated as an important factor in determining a satisfactory stocking density (Ewbank & Bryant, 1972) and failure to allow sufficient space appears to lead to a failure in communications between animals and an increase in social strife. With hens in groups of 10 and 30 confined to 0,346 m^2 and 0,115 m^2/bird Craig, Biswas & Guhl (1969) found an increase in agonistic interactions with increased crowding and the distance between nearest neighbours also tended to increase with crowding.

The importance of stocking density, in a practical sense, will however be most obvious if the economic performance of the animal, i.e. its rate of gain or feed conversion efficiency can be shown to be affected. Unfortunately there is a lack of complete agreement although the tendency is to suggest that liveweight gain deteriorates as area per animal decreases. For example, with pigs fed ad libitum and housed at 0,74; 1,49 and 2,33 m^2/ pig Noland, Scott & Angus (1959) reported a decrease in liveweight gain with a decrease in space allowance but Nofziger (1960) using similar space allowances found no differences in performance. At even more intense stocking rates Heitman, Hahn, Kelly & Bond (1961) have indicated that pigs housed at 1,86 m^2/pig grow faster than pigs housed at 0,93 m^2 and 0,46 m^2 and that those housed at 0,46 m^2 had the poorest feed conversion efficiency. Using stocking rates of 0,36 m^2; 0,54 m^2 and 0,72 m^2 Jensen, Becker & Thatcher (1962) found that only after a bodyweight of 55 kg had been attained did the liveweight gain of the pigs at 0,36 m^2 become slower than that of the others. With the growing/finishing pig it would appear that the effects of stocking density could be reduced if the area allowed per pig was adjusted in accordance with body size. As a result of adjusting space allowance in accordance with bodyweight, Gehlbach, Becker, Cox, Harmon & Jensen (1966) found no differences in feed conversion efficiency although at elevated air temperatures liveweight gain increased with space allowance.

Population density, as manipulated by group size, has also been shown to have some effects and Heitman *et al.* (1961) using groups of 3, 6 and 12 pigs found that at the small group size pigs increased their voluntary feed intake but feed conversion efficiency was depressed. Although there would appear to be many factors which could influence the results of these experiments and so lead to the lack of consistency in the results it could be postulated that social rank may have sufficiently influenced feed intake to account for the differences. The inability of pigs, through excessive concentration of animals in a given space or through the adverse geometry of that space and the unsatisfactory disposition of feeders, waterers etc. to move freely to feed and drink may influence voluntary feed intake and so depress liveweight gain. Where pigs are fed a restricted quantity of food the influence of population density on economic performance would not appear to be so marked provided adequate feeder space for all pigs is allowed.

With some animals however, e.g. pregnant sows, group behaviour has been eliminated entirely by confining individuals to boxes or stalls or tying them by the neck. Such practices tend to eliminate the physical effects of fighting and perhaps to simplify the management of larger numbers of animals, but it may not reduce psychological stress. Sows confined to individual stalls do appear to exhibit signs of behavioural aberration, e.g. the continual mouthing or biting of metal bars but apart from similar observations little is known of the physiological or behavioural aspects of such systems.

In economic terms, Laird & Walker-Love (1972), having compared the performance of gilts individually housed and in groups of four in outside yards, concluded that there was no evidence that the performance of the gilts and later the same animals as sows, were adversely affected by confinement during pregnancy. Although the farrowing interval was longer in the stall system the number of piglets born alive was higher in the individual accommodation than in the grouped sows. England and Spurr (1969) similarly concluded from a comparison of sows housed in groups and sows housed individually that there appeared to be no significant effects of confinement on any aspect of reproductive abilities but some gilts did fail to exhibit normal oestrus and mating behaviour. Practical observation would appear to substantiate this.

Conclusions

Intensive animal production would appear to be an expanding area of development and intensive housing is merely one facet of production. There are many important aspects of intensive livestock management associated with housing such as the disposal of animal wastes or the mechanisation of feed handling which could have been discussed at great length but which have been avoided on the grounds that they do not directly affect the physiology or biological performance of the animal. In considering the main features of the development of intensive housing, two aspects have been emphasised, the gradual elimination of litter and the improvement of space utilisation. For example in housing systems where the objective is to eliminate bedding it has been shown that greater control of the thermal environment must be maintained by the stockman if he is to compensate for the lack of straw and the facilities for the animal to choose a comfortable environment. Similarly with restrictions on space it has been indicated that as the natural ability of the animal to select its own social environment is reduced then compensation for the resultant stress must be expected by physiological or behavioural means.

The effects of stocking density on such economic factors as liveweight gain and feed conversion efficiency have also been discussed. There is little doubt that the word 'intensive' is descriptive of many current practices in animal production but the question is now, how far can those techniques be advanced before moral and ethical considerations become paramount. For example, in re-examining the original recommendations for the Codes of Welfare, the Farm Animal Welfare Advisory Committee (1970) presented their deliberations under both 'Scientific' and 'Ethical' considerations.

Intensive animal production has yet to achieve its full potential (Braude, 1970) and the technological parameters associated with developing this potential will continue to progress along the lines described in this paper. The most recent example of intensive pig production is typical of this trend. Systems of early weaning of pigs from seven days of age are in the process of development where animals of up to 5 kg liveweight are group housed in litterless wire cages stacked in three tiers thereby achieving a total space utilisation of approximately 0,097 m^2 of total floor space per pig (including service passages) (Baxter, 1972).

Optimum thermal conditions must be achieved by a high investment in quality structures and sophisticated heating, ventilating and environmental control equipment. For example it is recommended that piglets of approximately 10 days of age should be housed in cages at an air temperature of 27 to 29°C (constant), a relative humidity of 60% and that air movement should not exceed, 0,15 m/s (Debruyckere, 1970). It has also been reported that pigs reared in this system react markedly to a 10% change in air humidity and as little as a 2°C change in temperature should this occur within a period of 30 min (Van der Heyde, 1970). And finally, Van der Heyde (1970) has suggested that when piglets in cages are disturbed during their normal resting period excessive inter-sucking and biting occurs and as a result the cage rearing rooms should be isolated from abnormal sounds or vibrations and rearing is best accomplished in complete darkness except when the troughs are cleaned and refilled with feed. This level of building and environmental sophistication has never before been applied to commercial animal production and it is in sharp contrast to spacious, deep strawed conditions of traditional farming but it may be the way of the future.

If we are on the one hand to satisfy the demand for meat by intensive animal production methods and on the other to maintain ethical standards, then agricultural building technology must be firmly established on a zoocentric basis in which studies in physiology, zoometry, ethology and biomechanics play a major role.

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