Evaluation of a new three-phase technology pig housing on pig farm with capacity of 12000 pigs per year at the designing stage

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Abstract. Currently, in Russia, the North American technology of keeping pigs with a combined rearing and fattening area (CFSWP) is becoming widespread. It is essentially a two-phase technology for keeping pigs. Many years of research conducted by the authors of the article have shown that the most effective technology is a stress-free methods of keeping pigs. However, its usage is limited by the capacity of the pig farm and the size of the pigsties. A new technology with elements of stress-free pig housing has been developed for a pig farm for the reproduction, rearing and fattening of 12000 pigs per year with a combined sow farrowing and weaning piglet rearing area (CFSWP) in order to form piglets nests at the stages of the suckling period and rearing. Thus, the usage of the new technology is appropriate for pork production industrial enterprises. The usage of this solution allows you to limit the impact of stress on piglets at the most vulnerable stages of cultivation – the suckling period and rearing. The new technology is compared with a standard project that is widely used in Russia according to the developed author's methodology. The evaluation criteria are the following indicators: the usage of the area of the main purpose and the payment of the area by the production of meat. Despite the fact that the marketable weight of pigs on a farm with the new technology is only 3.8% higher, the payment criterion for the main purpose area is 1.39-1.4 times more effective in comparison with the basic technology. The use of the new three-phase technology with CFSWP will reduce the total area of suckling sows, weaned pigs and fattening pigs by 9.5 %, and increase the productivity of weaned pigs and fattening pigs by 10%.

1. Introduction
From the analysis of the performed scientific research, as well as the experience of operating pig farms in our country and abroad, the following technologies of reproduction, cultivation and fattening of pigs are known [1-3]:

- Single-phase family-nest;
- 2-, 3- and 4-phase traditional;
- 2-, 3-, 4- and 5-phase stress-free;
The North American Hot-Slat technology with combined rearing and fattening areas (CFSWP), successfully implemented in Russia (at the pig complex for 11.6 thousand sows of Cherkizovo LLC) [4-5]. "Wean to finish" is a maintenance scheme in which piglets are transferred to the premises of a pigsty-fattening house immediately after weaning from sows, in which they will remain until they gain the necessary marketable weight.

If the traditional technology of cultivation of pigs moved twice: from farrowing to the site of rearing and the rearing to the fattening area, the technology WTF – once from the farrowing area to the combined Wean-to-Finish. Also, along with reducing labor costs, reducing mortality, increasing productivity, and more efficient use of usable area, according to the results presented by producers using WTF technology, pigs reach the commercial scale often up to 10 days earlier than with traditional keeping technology. It is known that the body's resistance to stress is accompanied by a drop in the growth rate of live weight of growing young animals, an increased level of culling of productive livestock due to a variety of reasons [6].

Similar results were obtained on a small pig farm for 500 pigs per year with a five-phase stress-free method of keeping in a farm in the Tver region [7-8].

Two, three, four and five-phase stress-free methods of keeping pigs consist in keeping them at the farrowing, rearing and fattening stages of the same duration in days with the farrowing and suckling stage, self-forming grouped adjacent nests, and the transfer from section to section is carried out by their independent free transition using the food search reflex.

These methods ensure more precise compliance with the technology and production rhythm, regulate the frequency of use of premises, fully guarantee the sanitary and veterinary well-being of all age groups of pigs, allow the most rational use of the useful area of the main purpose due to the use of machine equipment that most fully corresponds to the size of animals at each stage of their cultivation and fattening [9].

The new technology, which is being considered at the conceptual design stage, provides for a combined section for farrowing sows and rearing weaned piglets, consisting of three pigsties, each of which contains an isolated section for farrowing 48 sows (in the central part of the building) and two isolated sections on each side, for rearing up to 600 weaned piglets each. Between each pair of machines for farrowing sows, an inter-station manhole is provided for the transition and communication of piglets from adjacent machines. Opposite each two adjacent machines, hermetically sealed manholes are provided in the intersectional walls of the sections for farrowing sows and rearing piglets, which are used for independent non-forced transition of weaned piglets.

The signal for the transition of piglets at 28-29 day suckling period is: the lights in sections for rearing of piglets weaned, the opening of the intersection of lazy one isolated section for the rearing of pigs, distribution of feed and opening machine of the fence for farrowing sows. The transition can take place within 1-2 days [10]. After closing the intersectional manholes, the sows are driven to the site for keeping single sows and insemination, and the isolated section for farrowing sows is thoroughly washed, sanitized and disinfected for 2-3 days. When new technology like the WTF is only one forcible transfer of piglets weaned grouped nests from isolated sections for rearing pigs pigsty for the sow of Swinnerton and rearing of piglets in the insulated section, for pigs a pigsty of a feed yard is a continuation of the combined site of farrowing of sows and rearing of weaned piglets (CFSWP) (through the connecting corridor).

In accordance with the main technological parameters given in table 1, the technological calculation of the livestock and the number of machine seats was carried out and the technological model was developed (table 1). A line-up of pig farms with an explication of pig staging areas, the size of sections, machines and aisles [11].

The assessment of the developed three-phase technology with elements of stress-free content is made in comparison with the three-phase technology of reproduction, cultivation and fattening of 12000 pigs per year, widely spread in Russia and Belarus (table 2) developed by the Neofors group of companies according to the author's method [13-14].
Table 1. Main technological parameters of the considered technologies for pig farms per 12,000 pigs per year [12].

| No | Name of indicators | Technology under development | The underlying technology «Neofors» |
|----|--------------------|------------------------------|-----------------------------------|
| 1. | Production program, head / year | 11500-15000 | 11500-15000 |
|    | Including the estimated | 13275 | 13140 |
|    | Main sows, head | 545 | 545 |
| 2. | The rhythm of production, days | 14 | 7 |
| 3. | Number of farrowings per year from one sow | 2.295 | 2.295 |
| 4. | Duration of the period: | | |
|    | - rest of the main sows, days | 18 | 18 |
|    | - conditional gestation of the main sows, days | 32 | 32 |
|    | - gestation of the main sows, days | 76 | 76 |
|    | - acclimatization of the main sows, days | 7 | 7 |
|    | - rearing of repair pigs, days | up to 100 | up to 100 |
|    | - stimulation of repair pigs, days | up to 56 | up to 56 |
|    | - suction period, days | 28-30 | 32 |
|    | - rearing of weaned piglets, days | 70 | 53 |
|    | - fattening of pigs, days | 70 | 95 |
| 5. | Average daily live weight gain: | | |
|    | - suckling period, gr/day | 260 | 240 |
|    | - the period of rearing, gr/day | 580 | 450 |
|    | - the period of fattening, gr/day | 860 | 780 |
| 6. | Unsuccessful pregnancy, % | 15-25 | 15-25 |
| 7. | Culling of sows/boars, % | 45/45 | 45/45 |
| 8. | Duration of rehabilitation of premises, days | 2-3 | 2-3 |
| 9. | The estimated safety of the livestock, %: | | |
|    | - suckling period | 94 | 94 |
|    | - growing period | 96 | 95 |
|    | - fattening period | 98 | 98 |
| 10. | Size of the group of sows accepted for farrowing, head | 48 | 24 |
| 11. | The number of piglets in the farrowing, head | 11-13.9 | 11-13.9 |

2. Materials and methods

This project has been implemented many times, is constantly updated and takes into account the latest developments of science and practice.

In table 2, the length of the passages is taken in accordance with the length of the isolated sections.

As a criterion for choosing technological planning solutions at the initial stage of conceptual design, the following criteria were adopted: $F_{con}$ - use of the main purpose area (m²×days) and the criterion for paying for the main purpose area by meat production $K_m$ (kg/m²×days) [15-16].

The criterion for paying for the area of the main purpose of meat production is determined by the formula:

$$K_m = \frac{M_T}{F_{PON}}, \frac{kg}{m^2 \times days}$$  \hspace{1cm} (1)

Where $M_T$ – commercial (live) weight of raised pigs per year, kg.

Since the maintenance of an adult brood herd (idle, repair, sows of the 1st and 2nd periods of gestation will be carried out in the same building as in the project-analogue of the pig farm for 12000 pigs per year of the «Neofors» company, $F_{pon}$ is determined by formula 2 only in pigsties for farrowing sows, raising suckling pigs, rearing weanling pigs and fattening pigs:
\[ F_{PON3f} = F_{O3f} + F_{P3f} + F_{D3f}, m^2 \times \text{days} \]  

Where: 
- \( F_{O3f} \) – the utilization of the easel area, \( m^2 \times \text{days} \);  
- \( F_{P3f} \) – the utilization of square passes, \( m^2 \times \text{days} \);  
- \( F_{D3f} \) – indicator of the use of additional space required for cleaning, washing, sanitary repairs and disinfection of premises and machine equipment after the end of the production cycle, \( m^2 \times \text{days} \).

**Table 2.** Technological layout of pig farms with explication of production sites, dimensions of sections and machines.

| Name of the area | Number of sections and their capacity | Dimensions of sections, m | Bench dimensions, m |
|------------------|--------------------------------------|---------------------------|-------------------|
| Pig farm for 12,000 pigs per year with CFSWP | 1 section with 208 seats for single, conditionally pregnant and repair sows on rearing in individual machines, test boars in individual mills and repair pigs on stimulation | | |
| Pig farm for 12 thousand pigs per year «Neofors» | 1 section with 208 seats for single, conditionally pregnant and repair sows on rearing in individual machines, test boars in individual mills and repair pigs on stimulation | | |
| Pig farm for 12,000 pigs per year with CFSWP | 1 section for 280 pregnant sows | \( L_c = 29.4 \) | \( b_c = 24.3 \) |
| Pig farm for 12 thousand pigs per year «Neofors» | 1 section for 280 pregnant sows | \( L_c = 36.0 \) | \( b_c = 24.3 \) |
| Pig farm for 12,000 pigs per year with CFSWP | 3 sections for 48 suckling sows each | \( L_c = 45.6 \) | \( b_c = 24.3 \) |
| Pig farm for 12 thousand pigs per year «Neofors» | 6 sections for 600 weaned piglets each | \( L_c = 54.2 \) | \( b_c = 24.3 \) |
| Pig farm for 12,000 pigs per year with CFSWP | 14 sections for 200 fattening pigs each | \( L_c = 72.6 \) | \( b_c = 24.3 \) |
| Pig farm for 12 thousand pigs per year «Neofors» | 1 section for 120 weaned piglets each | \( L_c = 10.8 \) | \( b_c = 24.3 \) |
| Pig farm for 12,000 pigs per year with CFSWP | 2 sections for 300 weaned piglets each | \( L_c = 10.8 \) | \( b_c = 24.3 \) |
| Pig farm for 12 thousand pigs per year «Neofors» | 1 section for 120 weaned piglets each | \( L_c = 10.8 \) | \( b_c = 24.3 \) |
| Pig farm for 12,000 pigs per year with CFSWP | 1 section for 120 weaned piglets each | \( L_c = 10.8 \) | \( b_c = 24.3 \) |
| Pig farm for 12 thousand pigs per year «Neofors» | 1 section for 120 weaned piglets each | \( L_c = 10.8 \) | \( b_c = 24.3 \) |
| Pig farm for 12,000 pigs per year with CFSWP | 1 section for 120 weaned piglets each | \( L_c = 10.8 \) | \( b_c = 24.3 \) |
| Pig farm for 12 thousand pigs per year «Neofors» | 1 section for 120 weaned piglets each | \( L_c = 10.8 \) | \( b_c = 24.3 \) |
For technological planning solutions of pigsties for farrowing sows, raising suckling pigs, rearing weaned pigs and fattening pigs, developed at the stage of conceptual design of a pig farm for the reproduction, cultivation and fattening of 12000 pigs with elements of stress-free maintenance and a comparable pig farm for 12000 pigs per year of the «Neofors» company, \( F_{O3f} \) is determined by the formula:

\[
F_{O3f} = N_{COP} \times (n_{COP} \times (l_{COP} \times h_{COP})) \times n_{DOP} + N_{CD} \times (n_{CD} \times (l_{CD} \times h_{CD})) \times n_{DD} + \\
+ N_{CO} \times (n_{CO} \times (l_{CO} \times h_{CO})) \times n_{DO}, \text{m}^2 \times \text{days}
\]

Where:
- \( N_{COP} \) – number of isolated sections for farrowing sows and raising suckling pigs;
- \( n_{COP} \) – number of benches in each isolated section for farrowing sows and raising suckling pigs;
- \( l_{COP} \) – length of the bench for farrowing sows and raising suckling pigs, m;
- \( h_{COP} \) – depth of the bench for farrowing sows and raising suckling pigs, m;
- \( n_{DOP} \) – duration of keeping suckling sows with suckling piglets, days;
- \( N_{CD} \) – number of isolated sections for weaning piglets;
- \( n_{CD} \) – number of bench in each isolated section for rearing weaned piglets;
- \( l_{CD} \) – length of the bench for rearing weaned piglets, m;
- \( h_{CD} \) – depth of the bench for rearing weaned piglets, m;
- \( n_{DD} \) – duration of growing of weaned piglets, days;
- \( N_{CO} \) – number of isolated sections for fattening pigs;
- \( n_{CO} \) – number of benches in each isolated section for fattening pigs;
- \( l_{CO} \) – length of the bench along the feeding front for fattening pigs, m;
- \( h_{CO} \) – depth of the bench for fattening pigs, m;
- \( n_{DO} \) – duration of fattening of pigs, days.

According to formula 3, we also determine the indicator of the use of machine area for the developed three-phase technology with elements of stress-free content - \( F_{O3feb} \) and three-phase technology of the analog object-a pig farm for 12000 pigs of the «Neofors» company - \( F_{O3fN} \).

The coefficient that characterizes the ratio of the area of passages of technological planning solutions for the designed and similar technology is determined by the formula:

\[
\delta_{3feb,3fn} = \frac{\sum f_{P3feb,3fn}}{\sum f_{C3feb,3fn}} \quad (4)
\]

Where:
- \( \sum f_{P3feb,3fn} \) - total area of aisles of technological planning solutions for the designed and compared technology, m\(^2\);
- \( \sum f_{C3feb,3fn} \) - total area of sections for keeping all age groups of pigs of technological planning solutions for the designed and compared technology, m\(^2\).

The indicator of the use of the area of passages \( F_{P3feb,3fn} \) for planning solutions for the designed and compared technology is determined by the formula:

\[
F_{P3feb,3fn} = \delta_{3feb,3fn} \times F_{O3feb,3fn} \quad (5)
\]

The total area of passageways for the projected technological planning solution is determined by the formula:

\[
\sum f_{P3feb} = N_{COP} \times [n_{pr} \times (l_{PRCOP} \times b_{PRCOP}) + n_{pp} (l_{PPCOP} \times b_{PPCOP})] + \\
+ N_{CD} \times n_{pr} (l_{PRCD} \times b_{PRCD}) + N_{CO} \times n_{pr} (l_{PRCO} \times b_{PRCO}), \text{m}^2
\]

\( n_{pr} \) – number of longitudinal passages;
1. Formulas

The total area of passages for the compared technological planning solution is determined by the formula:

\[
\sum f_{3J,IN} = L_{CPPO} \times B_{CPCOP} + N_{CO} \times n_{pr} \times (l_{PRCOP} \times b_{PRCOP}) + \\
L_{CGCD} \times B_{CPCD} + N_{CD} \times n_{pr} \times (l_{PRCD} \times b_{PRCD}) + n_{pr} (l_{PPCD} \times b_{PPCD}) + \\
L_{CPCO} \times B_{CPCO} + N_{CO} \times n_{pr} \times (l_{PRCO} \times b_{PRCO}), m^2
\] (7)

The total machine area of sections for the maintenance of suckling sows, suckling pigs, weaning pigs and fattening pigs is determined by the formula:

\[
\sum f_{C3J} = N_{CO} \times (l_{CO} \times h_{CO}) + + N_{CD} \times (l_{CD} \times h_{CD}) + N_{CO} \times (l_{CO} \times h_{CO}), m^2
\] (8)

The indicator of the use of additional Ad area for cleaning, washing, sanitary repair and disinfection of premises for the maintenance of all age groups of pigs is determined by the formula:

\[
F_D = \frac{F_O + F_P \times T_D \times F}{T}, m^2 \times days
\] (9)

Where:
- \(T\) – duration of pig breeding from birth to completion of fattening and reaching marketable weight, days;
- \(T_D\) – duration of cleaning, washing, sanitary repair and disinfection of sections, days;
- \(F\) – phasing of the breeding method.

3. Results and Discussion

The results of determining \(F_{PON}\) in pigsties for farrowing sows, raising suckling pigs, rearing weaned pigs and fattening pigs per year of the developed three-phase technology with elements of stress-free maintenance (CFSWP) in comparison with the three-phase technology developed by the «Neofors» company are shown in table 3.

**Table 3.** Indicators of the use of the area of the main purpose for a pig farm for the reproduction, cultivation and fattening of 12000 pigs per year with various technologies.

| Developed and compared pork production technologies | Indicators of the use of the area of the main area for the cycle, \(F_{PON}\), m²×days | Total | Including |
|----------------------------------------------------|---------------------------------------------------------------------------------|-------|-----------|
|                                                      | \(F_{PON}\) | \(F_O\) | \(F_P\) | \(F_D\) |
| Traditional three-phase technology of growing and fattening 12000 pigs per year developed by the «Neofors» company | 543259.3 | 424090.06 | 93299.8 | 25869.44 |
| Three-phase technology of growing and fattening 12000 pigs per year with elements of stress-free maintenance is being developed | 392279.17 | 302890.77 | 69664.87 | 19723.53 |
| The ratio of decreasing | 1.38 | 1.4 | 1.34 | 1.31 |
Table 3 shows that technological planning solutions with elements of stress-free pig keeping (CFSWP) are preferable, since in terms of the use of the main purpose area and its components, it is much more efficient – by 1.31 – 1.4 times.

The results of the assessment of technologies for breeding pigs by the criterion of paying for the area with meat production are presented in table 4.

| Breeding technology                                      | $F_{PON}$, $m^2 \times$days (for year) | Commercial weight of pigs per year, $M_t$, kg | $K_{M_t}$, kg/$m^2 \times$days | Commercial weight of pigs (including culled and repaired sows) per year, $M_t$, kg | $K_M$ (taking into account the sale of culled and repaired sows), kg/$m^2 \times$days |
|----------------------------------------------------------|---------------------------------------|---------------------------------------------|---------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Traditional three-phase technology of growing and fattening 12000 pigs per year developed by the «Neofors» company | 543259.3                              | 1405903                                     | 2.58                            | 1481216                                                                         | 2.73                                                                            |
| Three-phase technology of growing and fattening 12000 pigs per year with elements of stress-free maintenance is being developed | 392279.17                             | 1420425                                     | 3.62                            | 1497813                                                                         | 3.81                                                                            |

4. Conclusion

Despite the fact that the marketable weight of pigs on the projected farm is only 3.8% higher, the criterion for paying for the area of the main purpose for a pig farm for 12000 pigs per year with the new technology of growing weaned pigs (CFSWP) is 1.39-1.4 times more effective in comparison with the basic technology.

In addition, labor costs are significantly reduced due to the self-formation of grouped nests and the independent movement of piglets by grouped nests.

The advantage of the new technology is also the presence, in contrast to the basic technology, in each isolated section for rearing piglets and fattening pigs, 2 sanitary machines for 15 heads for keeping sick and stunted piglets-weaners, and fattening pigs.

The developed method of choosing from a variety of known technologies is an effective tool for justifying technological planning decisions and technologies in general at the stage of conceptual design.

The use of a new three-phase technology with CFSWP will reduce the total area of suckling sows, wean pigs and fattening pigs by 9.5 %, and increase the productivity of wean pigs and fattening pigs by up to 10%.

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