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Biosecurity assessment of commercial pig farms in Santa Catarina, Brazil

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Abstract – The objective of this work was to develop an index of adequacy to minimum biosecurity conditions (IAB) to express the external biosecurity level of pig farms in the state of Santa Catarina, Brazil. Pig farms of producers registered in the database of Companhia Integrada de Desenvolvimento Agrícola de Santa Catarina were sampled through an online questionnaire, with 76 questions on farm identification, production system, relationship with the agroindustry, herd size, and external biosecurity. One hundred questionnaires were answered by the farmers, showing the existence, partial existence, or absence of biosecurity practices, with scores of 1.0, 0.5, and 0.0, respectively, used to calculate the IAB of each farm. The farrow to weaning farms were grouped into three categories of production units (farrow to finishing, farrow to rearing, or farrow to weaning) and two of relationships with the production chain (integrated or independent). The investments necessary to achieve the ideal biosecurity practices were estimated. The farms with a low IAB (< 40%) represented 33% of the total, and the remaining 67% of the farms were classified with a medium or high index, evidencing a good external biosecurity. The IAB can be used to measure the biosecurity of pig farms and, based on their classification, to support the design of intervention plans.

Index terms: disease control, farm capital, farm surveys.

Avaliação da biosseguridade de granjas comerciais de suínos em Santa Catarina, Brasil

Resumo – O objetivo deste trabalho foi desenvolver um índice de adequação às condições mínimas de biossegurança (IAB) para expressar o nível de biossegurança externa de granjas suinícolas, no estado de Santa Catarina, Brasil. Foram amostradas granjas de produtores registrados no banco de dados da Companhia Integrada de Desenvolvimento Agrícola de Santa Catarina, por meio de questionário online com 76 perguntas sobre identificação da granja, sistema de produção, relação com a agroindústria, tamanho do rebanho e biossegurança externa. Foram respondidos 100 questionários pelos produtores, tendo mostrado a existência, a existência parcial ou a ausência de práticas de biossegurança, com pontuações de 1,0, 0,5 e 0,0, respectivamente, utilizadas para calcular o IAB de cada granja. As granjas de produção foram agrupadas em três categorias de unidades de produção (ciclo completo, creche ou desmame) e duas de relação com a cadeia produtiva (integrada ou independente). Estimaram-se os investimentos necessários para atingir as práticas ideais de biossegurança. As granjas com baixo IAB (< 40%) representaram 33% do total, e o restante das 67% propriedades foram classificadas com índice médio ou alto, tendo evidenciado boa biossegurança externa. O IAB pode ser usado para medir a biosseguridade de granjas suinícolas e, com base na classificação delas, apoiar a elaboração de planos de intervenção.

Termos para indexação: controle de doenças, capital agrícola, levantamentos agrícolas.

Introduction

In 2020, Brazil was classified as the fourth largest exporter of pork meat worldwide, representing 10% of the global exports (USDA, 2022). The state of Santa Catarina stands out as the country's largest producer and, consequently, leading exporter of pork meat (ABPA, 2020). This was the first Brazilian state considered free of the foot-and-mouth disease (FMD) without vaccination and, in 2015, along with the state of Rio Grande do Sul, was also certified as free of classical swine fever by World Organization for Animal Health (WOAH, 2021).

In the state of Santa Catarina, pork production involves different production systems and relationships with the production chain. According to Associação Brasileira dos Criadores de Suínos (ABCS) (Mapeamento…, 2016), most farms belong to small producers, who may also raise dairy cattle in the same location, and are integrated with agroindustries or agricultural cooperatives, whereas few farms are large, specialized, and have leading-edge technology. In the first case, the farm is classified as integrated and, in the second, as independent, i.e., the farmers have a contract with an agroindustry or a cooperative, or are responsible for their own decisions regarding technical and biosecurity practices (Miele & Waquil, 2007).

Pig farms are classified according to their production systems, consisting of different production sites, as follows: farrow to finishing (FF), farrow to rearing (FR), farrow to weaning (FW), and finishing. Some farms may have two (FR and finishing) or three (FW, nursery, and finishing) sites for piglet production (Miele, 2006), aiming to interrupt the cycle of infectious disease transmission when supported by the adoption of different biosecurity measures (Whiting & Pasma, 2008).

Biosecurity is an essential tool to ensure the sanitary status and the competitiveness of pig production systems (Barcellos et al., 2008). In pig farms, the term biosecurity can be defined as a set of practices, rules, and behaviors adopted to prevent, in the herds, both the introduction and spread (external and internal biosecurity, respectively) of pathogens, whether viruses, bacteria, or parasites (Amass & Clark, 1999). An example of a usual biosecurity practice is the perimeter fence, since it prevents the entry of unauthorized people, vehicles, and other animals that can contaminate the herd (Silva et al., 2019). Moennig (2015) highlighted that these fences prevent the entry of feral pigs that can transmit classical swine fever.

However, several factors interfere in the adoption of biosecurity practices. Among them, the following stand out: the current Brazilian legislation (Silva et al., 2019); the farmer's knowledge of biosecurity (Pinto & Urcelay, 2003), perception of the positive impacts of biosecurity practices (Casal et al., 2007), level of education, experience in the business, and personality traits (Racicot et al., 2012); and the farmers awareness and relationship with the production chain (whether integrated or independent), the life span and number of workers in the facilities, and the workers' training in good practices (Silva et al., 2019).

To date, there is no legislation regarding biosecurity in Brazil. Nationwide, only the certified pig breeding farms, called Granjas de Reprodutores Suídeos Certificadas, have defined biosecurity standards according to Instrução Normativa No. 19, de Fevereiro de 15, 2002 (Brasil, 2002). These certified farms are responsible for the production and commercialization of swine breeders and boar semen (Brasil, 2002). Some Brazilian states, however, have created independently their own legislations, defining minimum biosecurity requirements for pig farms that produce piglets and pigs for commercial purposes (Adapar, 2018; Rio Grande do Sul, 2019).

In this scenario, it is important to monitor and benchmark, over time, the biosecurity practices that should be adopted or improved. For this, biosecurity scores are the most common type of assessment tool (Alarcón et al., 2021).

The objective of this work was to develop an index of adequacy to minimum biosecurity conditions (IAB) to express the external biosecurity level of pig farms in the state of Santa Catarina, Brazil.

Materials and Methods

The data used in the study are from small family farms, classified as piglet-producer units, responsible for most pork production in Santa Catarina, covering the western, midwestern, and southern regions of the state (Mapeamento…, 2016). The farms chosen as subjects were: FW and FR farms, with 200 or more sows; and FF farms, with 30 or more sows.

In October 2019, a list of 974 producers (126 farrow to finishing and 848 farrow to rearing or farrow to weaning) was obtained from the database of Companhia Integrada de Desenvolvimento Agrícola de Santa Catarina (CIDASC). A total of 100 subjects were selected using convenience sampling. The participation of the respondents was voluntary, with no financial reward, as agreed in the free and informed consent form at the beginning of the questionnaire. The study was approved by the ethics committee for research involving human subjects of Instituto Federal de Santa Catarina, under CAAE: 24660919.9.0000.8049. Data were collected from March to July 2020.

The applied questionnaire was online and structured. It was developed using Google Forms, based on a published document of Embrapa Suínos e Aves (Morés et al., 2017) and on a draft of a regulation establishing biosecurity measures for commercial pig farms in the state of Santa Catarina prepared by Secretaria de Estado da Agricultura e da Pesca (Santa Catarina, 2019). The link to access the online questionnaire was sent to the respondents by email or message through messaging app.

The questionnaire consisted of 76 questions divided into two categories: subject identification, including farm name, location, owner, contact, production system, relationship with the production chain, size of the breeding stock, and workforce; and external biosecurity practices, for information on isolation fence, disinfection system, presence of other animal species, downtime period, hand washing and disinfection, clothes and shoes changing, bathing room, changing room, bathroom, office, cafeteria, laundry, loading ramp, feed factory, storage room, carcass disposal, waste treatment, pest (insects and rodents) control, pig drinking water, and number of pig sources for replacement. The complete questionnaire is available at Repositório de Dados de Pesquisa da Embrapa (Zanella, 2023b).

The developed IAB was calculated based on the answers of the second category of questions. A total of 54 questions were selected to compose the IAB scores, which were 1.0, 0.5, or 0.0 when the biosecurity practice was present, partially present, or absent, respectively. For example, the answers to the question “Does the farm have a rodent control program?” scored 1.0 when “Yes, with auditable records”, 0.5 when “Yes, but without auditable records”, and 0.0 when “No”.

For each question, the respondent had to choose only one of the two or four/five possible answers. For most of the questions with two possible answers, the score was either 1.0 or 0.0, except in two cases in which it was 0.5 or 0.0. All three scores were used for the questions with four or five possible answers. The total score was 53. The adopted scoring criteria are available at Repositório de Dados de Pesquisa da Embrapa (Zanella, 2023b).

The IAB (in percentage) of each farm was calculated by summing the scores obtained for the adopted biosecurity practices and, then, dividing them by the total score. According to the IAB, the farm’s external biosecurity level was classified as: low, when IAB $< 40\%$; medium, when $40\% \leq$ IAB $< 70\%$; or high, when IAB $\geq 70\%$.

The farms were also classified into the five following categories, combining their production site (FF, FR, or FW) and their relationship with the production chain (integrated or independent): independent FF, independent FR, independent FW, integrated FR, and integrated FW; there was no integrated FF farm in the survey.

The secondary data obtained in 2020 were used to estimate external biosecurity investments in external fence, disinfection system, and office and changing rooms. To determine investments in external fence, both fence structure and price were taken into account. For the ideal fence (with a height of 1.5 m, concrete posts of 10x10 cm placed every 2.5 m, 6.3x6.3 cm stainless steel wire mesh, and a 10 cm high concrete base wall), the price per linear meter was R$104.61, estimated based on Sistema Nacional de Pesquisa de Custos e Índices da Construção Civil for the state of Santa Catarina (Brasil, 2020). However, for fences that were not 10 cm high and did not have a concrete base wall, the price was R$29.56 per linear meter. The perimeter of the fences was calculated considering a fence length/sow ratio of 21, 28, and 107 m for the FW, FR, and FF farms, respectively.

According to local suppliers, the price for the disinfection system was R$16,120.00. To calculate the price of the office and changing rooms, the ideal area (in square meters) for both was determined considering the sows/number of workers (n) ratio, which was 200, 150, and 60 for the FW, FR, and FF farms, respectively. The following two equations, defined

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by norm ABNT-NBR-9050 (ABNT, 2015) and Norma Regulamentadora No. 17 (Brasil, 1978b), were used:

$$A_{cr} = 1.5\frac{n}{1{,}000} \quad \text{and} \quad A_{of} = 7 + 4xn$$

where A_{cr} and A_{of} are the ideal areas of the changing and office rooms, respectively.

The price per square meter of the office room was defined according to the basic cost for a housing unit (BUC) in the state of Santa Catarina, whereas the price per square meter of the changing room was 1.5 times the BUC (CBIC, 2020).

For comparison purposes, the total investment of each farm, representing all assets required for an ideal biosecurity, was estimated using the values presented in Table 1. In addition, the investment per sow was also determined for each production site using the aforementioned equations and calculation methods. For example, the investment necessary for a FF farm with 350 sows was estimated by multiplying the 350 sows by R$7,616.00 per sow, resulting in a total investment of R$2,665,600.00.

A second investment, named biosecurity investment, was calculated based on the assets reported in the questionnaire, which were the same used to determine the total investment.

The estimation of the investments was impacted by the current coronavirus pandemic since the construction sector presented a shortage of supplies, causing an increase in the price of several products (Bezerra, 2020).

MS-Excel was used to tabulate the data and to calculate the IAB, total investment, and biosecurity investment. The descriptive statistical analysis was carried out using the R, version 4.2.2, software (R Core Team, 2022). The used packages were: lmtest, to check statistical assumptions; ggplot2, to plot the boxplot graphs; and plyr and dplyr, to carry out data manipulation and batch calculation. The IAB was checked for normality using Shapiro-Wilk's test (α=0.05), and the assumption was not met ($W = 0.94374$, $p<0.05$). Durbin-Watson's test was used to check the independence of residuals for IAB = f (TP, ESC, INV, PES), where TP is the category of the farm, ESC is the number of sows, INV is the necessary investment, and PES is the number of workers. The used statistics were: DW = 2.4229, p = 0.017, d_L = 1.592, and d_U = 1.758 (n = 100, k = 4). In this case, the assumption of the independence of residuals was not met, and the IAB presented a negative autocorrelation. Homoscedasticity was checked using Bartlett's test, with IAB = f(TP) being homoscedastic for $\alpha = 0.05$ (B = 6.0625, p = 0.1945). Kruskal-Wallis' test was used to compare IABs among the different farm categories.

Table 1. Criteria used to budget investments on biosecurity structures according to the pig farm production site.

Criterion[1]	Farrow-to-weaning farms	Farrow-to-rearing farms	Farrow-to-finishing farms
Total investment (BRL per sow)	4,979	5,439	7,616
Employees (sows per worker)	200	150	60
Land area (m^2 per sow)	15	22	64
Length-to-width ratio	2:5	3:5	1:5
Perimeter (meter per sow)	21	28	107

[1]BRL, Brazilian real.

Results and Discussion

The use of an online questionnaire has its advantages, such as the possibility of including a large number of subjects and its low execution cost (Boklund et al., 2004). However, part of the quality of the survey depends on the preciseness of the metadata available, that is, of the information about the subjects. Some producers, for example, may have been incorrectly registered or their profile information may have not been updated in the CIDASC database, which may be an indicative that the number of FF farms recorded there is probably underestimated. Inherent bias also affects the quality of an online survey; in this case, some farmers who were not comfortable using information technology, as apps and computers, probably had trouble answering the questionnaire, whereas others may have had their answers filtered by the technician designated by the agroindustry or the cooperative to help them fill out the form. Moreover, it is likely that the farmers more interested in biosecurity were those more prone to participate in the survey. Finally, since the survey was not carried out in loco, the minimum biosecurity conditions of the farms may not correspond to reality, meaning that more improvements may be necessary than what was assessed (Sahlström et al., 2014).

The 100 farms evaluated through the answered questionnaires represented 10.38 and 9.52% of the total number of piglet-producer units and FF farms in the state of Santa Catarina, respectively. Regarding their production system, 57 farms were FW, 31 were FR, and 12 were FF. As to their relationship with the supply chain, 79 farms were integrated with companies or cooperatives, whereas 21 were independent. The herd size median was 495 sows, ranging from 32 to 3,000 sows. The total investment median to achieve an ideal sanitary status was R$2,576,632.00, with a minimum value of R$243,712.00 and a maximum one of R$16,317,000.00. In the state of Paraná, Brazil, Stoffel & Rambo (2022) found that R$541,112.40 was the investment necessary for an integrated pig finishing farm designed to produce 1,365 animals per production batch. However, in the country, most studies on pig farms focus on the analysis of production costs (Araújo et al., 2016; Portes et al., 2019; Alves et al., 2022) and not on needed investments. In addition to this lack of studies, the reality of pig production in the state of Santa Catarina is quite diverse, which leads to the conclusion that any attempt to estimate a common figure would only be an approximation.

The minimum biosecurity investment median was R$61,774.00 per farm, with a minimum value of R$0.00 and a maximum one of R$174,336.00. The number of workers median was 3, with a minimum of 1 worker and a maximum of 21 workers, with 2 workers in the first quartile and 6 in the third. The workforce values found in the present study are close to the average reported by Beker et al. (2022), which was of 2.3 to 3.8 workers in each integrated pig farm in 23 municipalities, in the Itajaí Valley, in the state of Santa Catarina.

According to sanitary standards, only 23% of the farms had compliant fences and 9.0% had compliant disinfection systems. In terms of assets, 46, 38, and 38% of the farms had compliant loading ramps, office rooms, and changing rooms, respectively.

To better analyze the biosecurity of each farm, given the observed diversity, the studied sample was divided into more meaningful groups. Grouping according to production site showed that the FW and FR farms had a similar number of sows, number of workers, and total investment, with medians of 530 and 500 sows, 3 and 4 workers, and R$2.6 and 2.7 million, respectively. However, the IAB and biosecurity investment of these farms differed, with medians of 69.8 and 58.5% and R$55,774.00 and 69,949.00, respectively. These results are an indicative that the IAB was able to summarize the overall biosecurity efficiency of the farms. The FW farms, with the best IAB, required less capital and fewer workers to take care of a larger herd, showing more technical and economic efficiency. Contrastingly, the FF farms had a much smaller herd size, fewer workers, and a lower total investment, with medians of 69.5, 1.5, and R$0.5 million, respectively. Therefore, technically and economically, the FF farms were less efficient, showing a required biosecurity investment (median of R$62,682.50) as high as that of the FW and FR farms, the worst IAB (median of 21.7%), and a much higher number of workers per sow, being more prone to biosecurity risks. This is probably why no FF farm was integrated with an agroindustry or a cooperative.

Grouping farms according to their relationship with the production chain showed that integrated farms were more efficient and more compliant to minimum biosecurity requirements than independent farms. Although integrated farms required a total investment more than two-fold higher than that of independent farms, with medians of R$2.7 and 1.2 million, respectively, their herd size was also more than two times greater than that of independent farms, with medians of 530 and 220 sows, respectively. However, both farms showed a similar proportion of workers per sow of 132.5 and 110, respectively. Despite their smaller herd size, the independent farms would have to invest R$64,827.00 to achieve minimum biosecurity compliance, whereas integrated farms would have to invest less, R$58,685.00. This result is reflected on the IAB, which was 66% for integrated farms and 24.5% for independent farms. Therefore, the technical support provided by the companies or cooperatives seemed to have made a difference on the biosecurity status of the integrated farms.

According to the result of the Kruskal-Wallis' test, $H(4) = 32.995$, $p<0.05$, the five categories used to classify the farms differed among each other regarding the IAB. Out of the 100 farms assessed in the questionnaires, 32 had a high IAB, 35 a medium IAB, and 33 a low IAB. The farms belonging to the low IAB group, included 17 integrated farms and 16 independent farms. In terms of production sites, 11, 10, and 1 were FF, FR, and FW farms, respectively. This group of farms showed a herd size median of 300 sows, an ideal investment median of R$1,643,070.00, a biosecurity investment median of R$71,856.00 (representing 4.4% of the total investment), a number of workers median of 2, and an IAB median of 26.4%. Therefore, although the analysis of the IAB for the whole sample does not help to understand the observed diversity, it does inform the size of the problem.

The IAB was used to create a boxplot of each of the five categories (Figure 1), resulting in the two following groups: G1, formed by independent FF and independent FR farms; and G2, formed by independent FW, integrated FW, and integrated FR farms. The IAB median was the lowest (18.9%) for G1 and the highest (64.2%) for G2. Kruskal-Wallis' test was used to compare the categories in each group, showing no differences among them in G1, $H(1) = 0.0113$, $p = 0.9153$, and G2, $H(2) = 1.9055$, $p = 0.3857$.

Considering the greater risk of biosecurity according to the IAB, G1 would be the group of interest, with all 17 farms classified as independent and 12 as FF. The medians obtained for this group were: 100 sows for herd size; R$761,600.00 for ideal investment; R$64,616.00 for biosecurity investment, representing 8.5% of the total investment; 2 for number of workers, and 18.9% for IAB, whose maximum value was 47.2%.

The IAB used to categorize the farms and the metadata to provide the context for this categorization help to solve biosecurity problems by narrowing down solutions, facilitating the design of intervention strategies and improving their chances of success. According to the results obtained for G1, independent farms clearly need more technical support since the size of their herd is smaller and the investment required in biosecurity is high compared with their assets. Moreover, all 12 FF farms evaluated were grouped in G1, which shows their need for technical support in using technologies suitable for a small-scale production that requires a lower investment and covers the full production cycle.

The IAB also shows how complex a farm's reality is. For example, all respondents declared having a loading ramp in their farms, some built inside and others outside the perimeter fence. However, the survey showed that only 46% of the loading ramps

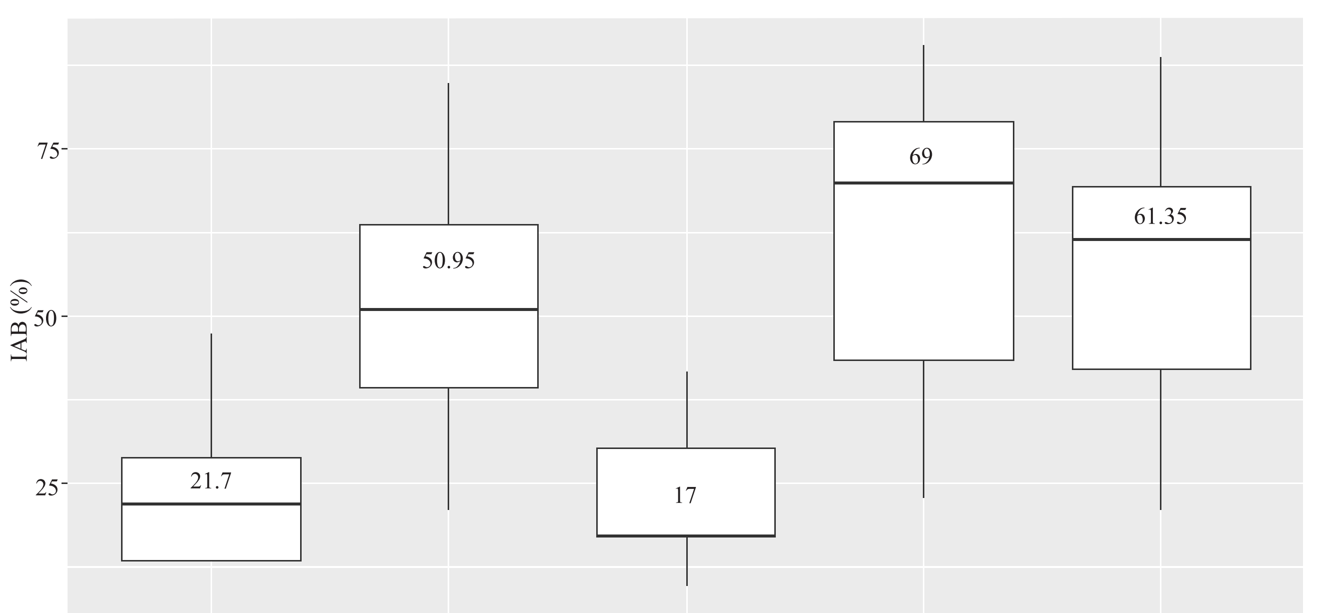

Figure 1. Boxplot of the developed index of adequacy to minimum biosecurity conditions (IAB) for the following farm categories: Indep FF, independent farrow-to-finishing farms; Indep FW, independent farrow-to-weaning farms; Indep FR, independent farrow-to-rearing farms; Integr FW, integrated farrow-to-weaning farms; and Integr FR, integrated farrow-to-rearing farms. The IAB median is highlighted.

were compliant to biosecurity standards. Therefore, the simple presence or absence of a specific practice is not enough to determine a farm's sanitary status.

This shows the importance of the IAB as a defining metric to support decision making when planning biosecurity measures as, for example, throughout the evolution of FF farms from full-cycle to multi-site (specialized) production (Whiting & Pasma, 2008). This evolution explains the worst and best sanitary status of these farms and of the FW farms, respectively. In the mid-1990's, FF farms, the oldest production system, were initially replaced by two production sites, FR and finishing farms (Miele, 2006), and then, more recently, by three sites, FW, nursery, and finishing farms (Nadal-Roig et al., 2019), aiming to interrupt the transmission cycle of infectious diseases.

The IAB also allows of estimating intervention expenses, which can be used to ground public policy decisions. For the low IAB group, the estimated biosecurity investment median was R$71,856.00 per farm, accounting for 4.4% of the total investment median of R$1.6 million per farm. Although apparently high, the estimated investments required to achieve minimum biosecurity compliance are lower than the economic impact that could be caused by an outbreak of a notifiable disease. It was estimated, for example, that an outbreak of African swine fever in the USA over 2 years could cause losses of US$ 15 billion (Carriquiry et al., 2020), whereas an outbreak of classical swine fever could cause economic losses of R$ 4.5 billion (approximately US $0.9 million) in the state of Santa Catarina (Brasil, 2019). Therefore, any effort of a farmer or government to increase biosecurity measures is more efficient in economic terms.

Conclusion

The developed index of adequacy to minimum biosecurity conditions can be used to measure the biosecurity of pig farms, classifying them in terms of biosecurity to support the design of intervention plans.

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