



## RESEARCH ARTICLE

# Specialists' Perspectives on Functional Egg Production: Awareness, Health Implications, and Regulatory Frameworks in Sudan

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## Abstract

**Background and Objective:** Functional eggs constitute a promising nutritional innovation aimed at mitigating micronutrient deficiencies and improving public health outcomes. This study assessed the perspectives of specialists and researchers on the production, health benefits, and regulatory requirements of functional eggs in Sudan.

**Materials and Methods:** A quantitative cross-sectional survey was conducted among 100 participants, including 37 specialists comprising animal nutritionists, veterinarians, and academic researchers. Data were collected using a structured online questionnaire administered via Google Forms and analyzed using descriptive and comparative statistics in SPSS.

**Results:** Specialists demonstrated the highest level of familiarity with functional eggs among all stakeholder groups, with 75.7% reporting good or very high knowledge. Scientific literature was the primary information source for 45.9% of respondents. Omega-3 fatty acids were identified as the most effective enrichment component (45.9%), and heart health (43.2%) and cognitive support (24.3%) were the most widely recognized scientifically validated benefits. However, respondents identified notable risks, particularly feed contamination (37.8%) and excessive additive use (32.4%). Key priorities for sector development included increased research funding (70.3%) and enhanced producer training (62.2%). Although 51.4% of specialists expressed strong willingness to recommend functional eggs, 61.1% perceived consumer awareness as low.

**Conclusion:** Sudanese specialists exhibit substantial technical readiness to support the development of a functional egg industry. Its success will depend on the establishment of robust regulatory frameworks, quality certification systems, and sustained research funding to mitigate safety risks and reduce the gap between scientific knowledge and consumer awareness.

## INTRODUCTION

Functional foods have become a central focus of nutritional research and market innovation worldwide, driven by the rising prevalence of non-communicable diseases and

persistent micronutrient deficiencies<sup>1</sup>. Among these innovations, functional eggs-defined as eggs whose nutritional composition is intentionally enhanced through dietary or management interventions-represent a versatile and potentially high-impact functional food platform<sup>2</sup>.

Although, conventional eggs are nutrient-dense staples, they often contain suboptimal levels of specific bioactive compounds, particularly long-chain omega-3 polyunsaturated fatty acids (PUFAs) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)<sup>3</sup>.

The nutritional plasticity of the hen's egg enables the efficient deposition of health-promoting compounds into the yolk through dietary manipulation<sup>2,4</sup>. Supplementation strategies using flaxseed, fish oil, or microalgae have been scientifically demonstrated to increase yolk concentrations of omega-3 fatty acids, which are associated with cardiovascular protection and improved cognitive function<sup>4</sup>. In addition, the inclusion of antioxidants, selenium and vitamins not only enhances the nutritional value of eggs for human consumption but also improves their oxidative stability<sup>5</sup>.

Despite well-established biological benefits, the production and utilization of functional eggs vary substantially across socio-economic contexts<sup>6</sup>. In high-income countries, these products occupy well-defined market niches supported by robust regulatory frameworks and high consumer awareness<sup>7</sup>. In contrast, in resource-constrained settings such as Sudan, functional eggs remain uncommon due to limited technical capacity, underdeveloped market infrastructure and economic constraints<sup>8</sup>. Transitioning from experimental production to a sustainable industry in such environments requires a multidisciplinary approach integrating scientific validation with policy and regulatory guidance<sup>9</sup>.

Specialists, including animal nutritionists, veterinarians, and food technologists, play a pivotal role in this transition by providing expert insights into feasibility, safety, and regulatory requirements for food-based interventions<sup>6</sup>. However, there is a notable lack of context-specific empirical evidence regarding how these experts perceive the opportunities and risks associated with functional egg production in Sudan<sup>10</sup>. Addressing this knowledge gap is essential for designing effective production strategies and market pathways tailored to local conditions. Accordingly, the objective of this study was to examine the perspectives of specialists and researchers in Sudan regarding the health benefits, scientific challenges, and regulatory frameworks necessary for the development of the functional egg sector.

## MATERIALS AND METHODS

**Study design and setting:** A quantitative, cross-sectional study design was employed to assess specialists' awareness, acceptance and professional perspectives regarding functional eggs. Data were collected internationally using

digital survey tools, with a strategic focus on Sudan in view of its expanding poultry sector and the limited availability of empirical evidence in this context.

**Study population and sampling:** The study population comprised 37 specialists, including animal nutritionists, veterinarians, poultry consultants, feed formulation experts, and academic researchers. Participants were recruited through a combination of non-probability convenience and purposive sampling techniques. The majority of respondents were Sudanese professionals (N = 35) specializing in animal production and veterinary sciences, thereby providing a multidisciplinary perspective across the poultry value chain.

**Data collection instrument:** Data were collected using a structured, English-language online questionnaire administered via Google Forms. The instrument was designed to capture comprehensive information across the following domains:

- **Demographic profile:** characterization of respondents by age, gender, education level, and years of professional experience
- **Technical familiarity:** Assessment of knowledge levels regarding functional eggs and primary sources of information
- **Nutritional and health evaluation:** Identification of effective enrichment ingredients (e.g., omega-3 fatty acids, vitamins) and recognized health benefits
- **Regulatory and scientific assessment:** Evaluation of perceived risks (e.g., feed contamination), regulatory oversight authorities, and scientific challenges

The questionnaire included a combination of multiple-choice items, Likert-scale statements, and closed-ended questions to ensure consistency and facilitate standardized quantitative analysis.

**Ethical considerations:** Ethical standards for nutritional and social research were strictly observed. Participation was voluntary and electronic informed consent was obtained from all respondents prior to data collection. To ensure confidentiality, no personal identifiers (e.g., names or telephone numbers) were collected, and all data were securely stored for academic purposes only.

**Data management and statistical analysis:** Responses were automatically captured in Google Forms and subsequently exported to Microsoft Excel for data cleaning and coding.

Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics, including frequencies, percentages, means and standard deviations, were used to summarize specialists' perspectives. Comparative analyses, such as cross-tabulations, were performed to explore associations between professional specialization, years of experience and levels of awareness.

## RESULTS

**Demographic and professional profile of specialists:** The study included 37 specialists and researchers (N = 37). The sample was predominantly male (81.1%), with 48.6% of respondents aged 31–40 years. Most participants were Sudanese nationals (94.6%), primarily specializing in Animal Production (48.6%) and Veterinary Medicine (29.7%). With respect to employment sector, 32.3% were affiliated with universities or research institutions, while 22.6% were employed in private clinics (Table 1). Professional experience

varied, with 45.9% reporting fewer than five years of experience and 16.2% reporting more than 20 years in the field.

**Awareness and information sources:** Specialists exhibited the highest level of technical familiarity with functional eggs compared with other stakeholder groups, with 75.7% reporting “good” to “very high” knowledge levels (Table 2). Scientific literature was identified as the primary source of information by 45.9% of respondents, followed by internet and social media (21.6%) and professional training programs (18.9%).

**Nutritional strategies and perceived benefits:** With respect to enrichment strategies, 45.9% of specialists identified omega-3 fatty acids (from fish oil or linseed oil) as the most effective ingredient for functional egg production, followed by vitamins and minerals (37.8%). The most frequently recognized scientifically validated health benefits were cardiovascular health (43.2%) and brain and nervous system support (24.3%), as presented in Table 3.

Table 1: Distribution of specialists by exact specialization and nationality (N = 37)

| Exact specialization         | Sudanese | Chinese | Jordanian | Total |
|------------------------------|----------|---------|-----------|-------|
| Animal nutrition             | 4        | 0       | 0         | 4     |
| Veterinary medicine          | 11       | 0       | 0         | 11    |
| Human medicine               | 0        | 0       | 1         | 1     |
| Academic researcher          | 1        | 0       | 0         | 1     |
| Animal production specialist | 18       | 0       | 0         | 18    |
| Food safety                  | 1        | 0       | 0         | 1     |
| Other                        | 0        | 1       | 0         | 1     |
| Total                        | 35       | 1       | 1         | 37    |

N represents the total number of specialists who participated in the study

Table 2: Level of familiarity and main sources of information among specialists

| Variables                      | Category              | Frequency (n) | Percentage |
|--------------------------------|-----------------------|---------------|------------|
| <b>Familiarity level</b>       | Very high             | 7             | 18.9       |
|                                | Good                  | 21            | 56.8       |
|                                | Limited               | 6             | 16.2       |
|                                | Heard only            | 3             | 8.1        |
| <b>Main information source</b> | Scientific research   | 17            | 45.9       |
|                                | Internet/social media | 8             | 21.6       |
|                                | Professional training | 7             | 18.9       |
|                                | Colleagues            | 5             | 13.5       |

Percentages are calculated based on a total of 37 respondents

Table 3: Specialists' perspectives on enrichment ingredients and health benefits

| Variables                     | Category                         | Frequency (n) | Percentage |
|-------------------------------|----------------------------------|---------------|------------|
| <b>Effective Ingredients</b>  | Omega-3 (fish/linseed oil)       | 17            | 45.9       |
|                               | Vitamins and minerals            | 14            | 37.8       |
|                               | Probiotics                       | 3             | 8.1        |
|                               | Yeasts                           | 2             | 5.4        |
|                               | Natural antioxidants             | 1             | 2.7        |
| <b>Proven health benefits</b> | Heart health                     | 16            | 43.2       |
|                               | Brain and nervous system support | 9             | 24.3       |
|                               | Prevention of chronic diseases   | 7             | 18.9       |
|                               | Immunity strengthening           | 5             | 13.5       |

Note: Ingredients and benefits identified as most effective according to specialist

Table 4: Perceived risks, challenges, and future spread of functional eggs

| Variables                      | Category                    | Frequency (n) | Percentage |
|--------------------------------|-----------------------------|---------------|------------|
| <b>Potential risks</b>         | Feed contamination          | 14            | 37.8       |
|                                | Overuse of additives        | 12            | 32.4       |
|                                | Lack of regulation          | 4             | 10.8       |
|                                | No major risks              | 5             | 13.5       |
| <b>Scientific challenges</b>   | Proving health benefits     | 14            | 37.8       |
|                                | Regulatory challenges       | 13            | 35.1       |
|                                | Ensuring production quality | 5             | 13.5       |
|                                | Other challenges            | 5             | 13.5       |
| <b>Future spread potential</b> | Very high/High              | 27            | 73.0       |
|                                | Moderate                    | 10            | 27.0       |

**Risks, challenges and regulatory oversight:** Respondents identified significant technical risks, particularly feed contamination (37.8%) and excessive use of additives (32.4%) (Table 4). Demonstrating health benefits was perceived as the primary scientific challenge by 37.8% of specialists, followed by regulatory constraints (35.1%). In terms of oversight, 45.9% identified the Ministry of Agriculture and Livestock as the primary regulatory authority, while 43.2% identified the National Standards Authority.

**Developmental priorities and future potential:** To promote sector development, specialists prioritized increased research funding (70.3%) and enhanced producer training (62.2%). Quality certification was considered the most effective mechanism for improving consumer trust by 47.2% of respondents. Although, 51.4% of specialists reported being “very willing” to recommend functional eggs, 61.1% assessed current consumer awareness as “low.” Overall, 73.0% of respondents rated the future market potential of functional egg products as “high” or “very high.”

## DISCUSSION

The findings of the present study provide a comprehensive professional perspective on the potential of functional eggs as a nutritional intervention in Sudan. The high level of technical familiarity reported by specialists (75.7%) distinguishes them as the most knowledgeable stakeholder group compared with consumers and farmers<sup>11</sup>. This expertise is largely attributable to their reliance on scientific research as a primary source of information (45.9%), consistent with global trends in which specialized knowledge underpins the development of functional food sectors<sup>6</sup>.

Consistent with the literature, specialists identified omega-3 fatty acids as the most effective enrichment ingredient, followed by vitamins and minerals<sup>4,12</sup>. This

consensus reflects the biological efficacy of incorporating fish oil, flaxseed, or microalgae to improve the lipid profile of egg yolks, a strategy well documented in previous studies<sup>4,13</sup>. The recognition of cardiovascular health and cognitive support as the principal benefits further reinforces the established role of long-chain polyunsaturated fatty acids (PUFAs) in reducing the risk of non-communicable diseases<sup>14-16</sup>.

Despite this technical readiness, specialists expressed substantial concern regarding production risks, particularly feed contamination (37.8%) and excessive additive use<sup>17,18</sup>. These concerns parallel documented challenges in resource-constrained settings, where inadequate regulatory oversight may compromise food safety<sup>6</sup>. The identification of the Ministry of Agriculture and the Standards Authority as the primary oversight bodies (over 80% combined) underscores the necessity of a national certification framework to manage these risks effectively<sup>17,18</sup>.

The “awareness gap” identified by specialists, who perceived consumer awareness as low (61.1%), represents a major barrier to market penetration<sup>6</sup>. This observation explains the continued niche status of functional eggs in Sudan, where high levels of scientific expertise have not yet translated into widespread public awareness<sup>6</sup>. To address this gap, specialists prioritized quality certification (47.2%) and awareness campaigns (33.3%) as the most effective strategies for building consumer trust<sup>19</sup>.

Finally, the study delineates a clear pathway for advancing the functional egg sector in Sudan. The high willingness of specialists to recommend these products (51.4% very willing) and their positive assessment of future market potential (73.0% high potential) indicate strong institutional support for nutritional innovation<sup>20,21</sup>. Nevertheless, successful sector development will depend on overcoming systemic constraints, primarily through increased research funding (70.3%) and enhanced technical training for producers (62.2%), which were identified as the highest priority actions<sup>20-22</sup>.

## CONCLUSION

This study demonstrates that Sudanese specialists possess a high level of technical awareness and scientific understanding of functional eggs, positioning them as key drivers for the development of this sector. Omega-3 enrichment was widely recognized as the most effective nutritional strategy, with cardiovascular and cognitive health identified as the primary benefits, reflecting strong alignment with international scientific evidence. Despite this technical readiness, significant challenges remain, particularly concerns related to feed contamination, additive overuse, regulatory constraints and the need to substantiate health claims. The identification of the Ministry of Agriculture and Livestock and the National Standards Authority as principal oversight bodies highlights the importance of establishing a coherent regulatory and certification framework to ensure product safety and quality. The findings also reveal a critical gap between specialist knowledge and consumer awareness, which currently limits market expansion. Addressing this gap will require coordinated efforts in quality certification, public awareness campaigns, and professional training. Moreover, increased investment in research and capacity building emerged as the highest development priorities. Overall, the strong willingness of specialists to recommend functional eggs, combined with their positive outlook on future market potential, indicates favorable conditions for sector growth. With appropriate policy support, regulatory infrastructure, and sustained investment in research and training, functional eggs have the potential to become a viable and impactful nutritional intervention in Sudan.

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