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Review Article

The Economics of Nutrition: Cost of Protein Fortification, Market Trends, and their Impact on Lung Function and Immunity

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Abstract

The global market for protein supplements and protein-fortified foods has grown into a multibillion-dollar industry, yet the respiratory consequences of this dietary shift have received little attention in the pulmonary literature. This review connects three threads that are usually examined in isolation: the economics of protein fortification, the consumer behavior that drives demand for high-protein products, and the clinical evidence linking protein intake to lung function and immune defense. Market analyses value the sector at roughly USD 28 to 63 billion in 2024 and 2025, with annual growth near 8 to 10 percent and a steady migration of buyers from athletes to older adults seeking protection against age-related muscle loss. Against this commercial backdrop, controlled trials and meta-analyses, though mostly of low certainty, associate adequate protein intake with better-preserved respiratory and skeletal muscle, a lower burden of the sarcopenia that complicates chronic obstructive pulmonary disease, and stronger immune competence during respiratory infection. The same products, however, carry a measurable burden of heavy-metal contamination, and chronic exposure to cadmium and lead is independently associated with impaired lung function and emphysema. Protein nutrition therefore sits at an underexamined intersection of commerce, public health, and respiratory medicine, and pulmonologists have practical reasons to ask patients what they consume. Priorities for future work include respiratory-specific protein intake guidelines, pharmacoeconomic analyses in respiratory care, and longitudinal monitoring of contaminant exposure in regular supplement users.

***Keywords**: Protein Supplementation; Food Fortification; Chronic Obstructive Pulmonary Disease; Sarcopenia; Respiratory Immunity; Gut-Lung Axis; Heavy Metal Contamination; Cadmium*

Introduction

The global protein boom and its health implications

Few categories of consumer nutrition have grown as quickly as protein. Market analyses place the global value of protein supplements between USD 28.5 billion and USD 63.1 billion across 2024 and 2025, with projections reaching USD 58 to 113 billion by the early 2030s, the range reflecting differences in methodology and product scope across reports [1,2]. Estimated annual growth rates cluster between 8 and 10 percent, and North America accounts for the largest regional share, between 35 and 41 percent of revenue [1,2]. Animal-derived proteins, principally whey and casein, still dominate sales, while pea and other plant proteins represent the fastest-growing segment [1].

What began as a niche aimed at bodybuilders has become a mainstream wellness commodity, and industry reports now identify older adults seeking to prevent age-related muscle loss as one of the most important emerging customer groups [2].

Table 1. The global protein-supplement market at a glance

Market metric	Reported value / trend	Source
Market value, 2024–2025	USD 28.5–63.1 billion	[1,2]
Projected value, early 2030s	USD 58–113 billion	[1,2]
Estimated annual growth	8–10% per year	[1,2]
Largest regional share (North America)	35–41% of revenue	[1,2]
Dominant product source (2025)	Animal-derived (whey, casein) ≈ 60% of the supplement market	[1]
Fastest-growing segment	Plant proteins, led by pea (hypoallergenic, sustainability appeal)	[1]
Key emerging demographic	Older adults seeking to prevent age-related muscle loss	[2]

Ranges reflect differing methodology and product scope across market reports [1,2]. Bracketed numbers follow the manuscript's reference list.

This expansion matters to respiratory medicine for a reason that is rarely stated. The demographic that the industry now courts for healthy aging overlaps substantially with the population that develops chronic respiratory disease, where nutritional status is a recognized determinant of outcome. Lower respiratory infections and chronic obstructive pulmonary disease (COPD) remain among the leading causes of death and disability worldwide, and protein-energy malnutrition continues to contribute to morbidity across age groups [3]. A consumer market built on the premise that more protein means better health is therefore operating, largely unexamined, in the same space where protein intake has genuine clinical consequences for the lungs.

Scope and objectives

This review reads together three bodies of literature that are seldom considered side by side. The first concerns the economics of protein fortification: what protein ingredients cost manufacturers, how fortification compares with other public health nutrition strategies, and what the economic burden of protein inadequacy looks like in respiratory disease. The second concerns consumer behavior, in particular the marketing claims and labeling practices that shape how people interpret the word "protein." The third, and the clinical core of the review, concerns the evidence linking protein intake to lung function, respiratory muscle integrity, and immune defense, together with the safety risks introduced by contaminants in protein products. The central argument is that decisions made in food manufacturing and marketing carry respiratory health consequences that the pulmonary literature has not adequately addressed. The sections that follow move from industry economics through consumer behavior to clinical outcomes, and close with the contaminant risks and research gaps that follow from this intersection.

The economics of protein fortification

The cost of protein ingredients and the structure of the market

Protein sources differ widely in price and in how they behave in a formulation, and they differ just as much in how consumers perceive them. These differences shape which proteins manufacturers add to foods and supplements. Animal-derived proteins held about 60 percent of the supplement market in 2025, a position attributed to their complete amino acid profiles and rapid absorption [1]. Plant proteins, led by pea, are growing fastest, helped by hypoallergenic positioning and sustainability appeal [1]. Beyond the raw ingredient,

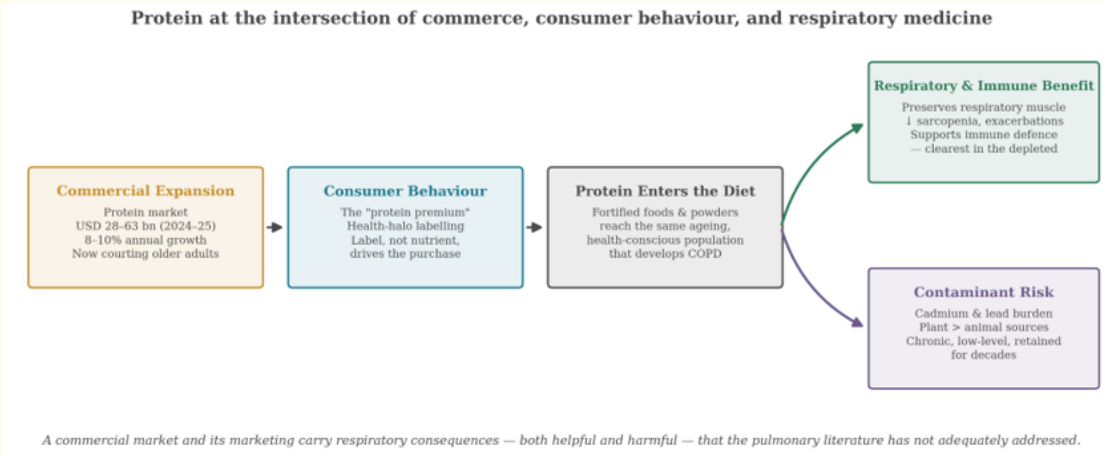

Figure 1

formulation adds cost through blending, flavor masking, and stabilization, all of which are necessary because added protein tends to degrade taste, a tension that consumer research has documented directly [4]. Granular, source-by-source pricing is poorly represented in the peer-reviewed literature, which is itself a limitation for any economic analysis of fortification and a point this review returns to in Section 7.

Fortification as a public health strategy

Food fortification has a strong economic case as a public health intervention, although the evidence base concerns micronutrients rather than protein. The most comprehensive economic evaluation to date examined 56 studies and more than 200 analyses across 63 countries, including over 40 low- and middle-income economies [5]. In that synthesis, 84 percent of fortification programs had incremental cost-effectiveness ratios below USD 1,000 per disability-adjusted life year (DALY) averted, and 58 percent fell below USD 150 per DALY averted in 2022 dollars; six of eight cost-utility analyses found fortification to be dominant, meaning it was both cheaper and more effective than the comparator [5]. These figures establish fortification as economically attractive in principle, but they describe iodine, iron, and vitamin programs in staple foods rather than the protein fortification of premium consumer products. The distinction matters, because the commercial protein sector adds protein to products that are already consumed by relatively well-nourished buyers, a different proposition from fortifying staples for deficient populations.

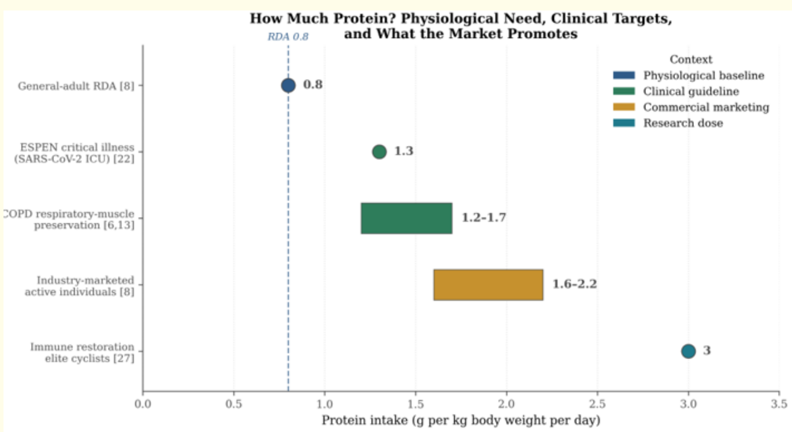

Figure 2

The economic burden of protein inadequacy in respiratory disease

The clinical economics of protein run in the opposite direction from the consumer market. The buyers who pay the protein premium are largely healthy adults, whereas the patients most likely to benefit, those depleted by chronic respiratory disease, are not the group the market is built around. Nutritional depletion, defined by low body mass index or low fat-free mass index, is a prevalent and independent predictor of mortality in COPD, and the European Respiratory Society has recommended systematic nutritional screening and integrated nutritional support as part of pulmonary rehabilitation [6]. The downstream costs of inadequate protein are visible in the consequences of sarcopenia, which independently predicts COPD exacerbations, hospitalization, and death, as Section 4 describes [7]. Framed this way, protein carries a double economic identity. It is a premium attribute sold to consumers who may not need it, and at the same time an underused clinical tool in populations where its absence drives expensive respiratory events.

Nutrition trends and the "Protein Premium"

Marketed intake versus physiological need

The gap between how much protein people are encouraged to consume and how much they actually require is wide. The recommended dietary allowance for protein is 0.8 g/kg/day, whereas the supplement industry typically promotes intakes of 1.6 to 2.2 g/kg/day for physically active individuals [8]. A review of common misconceptions about protein supplementation concluded that the frequently cited harms of higher intakes, including kidney damage, impaired bone health, and liver injury, are not supported by evidence in healthy adults, but the same review noted that data for people with chronic disease, including respiratory conditions, are sparse [8]. The practical consequence is a marketplace in which intakes well above physiological need are normalized for the general population, while the specific groups who might benefit clinically remain understudied.

Health halos and the labeling of protein

Consumer research shows that the word "protein" functions as a health signal independent of a product's actual nutritional quality. In a between-subjects experiment with 274 participants, placing protein in a product's title raised perceptions of overall healthfulness, an effect mediated by the assumption that the product also contained more of unrelated nutrients such as fiber and iron; conveying the same information through a "good source of protein" claim did not produce the generalized halo [9]. A survey of 1,022 adults comparing two real cereals found that the protein-labeled version was judged healthier despite containing more sugar and calories, with 54.5 percent of respondents perceiving no difference in sugar content, 57.3 percent more likely to buy the protein version, and 27.9 percent willing to pay a premium for it [10]. Sensory testing of identical vanilla yogurts reached a similar conclusion: a "high-protein" label raised liking scores, and respondents attentive to protein content reported feeling less full, which suggests that protein labeling may encourage rather than restrain consumption [11]. A discrete choice experiment extended these findings by showing that added-protein labels raise perceived healthfulness while lowering perceived tastiness, yet still command a measurable willingness to pay [4].

Table 2. The "protein premium": consumer studies on protein labelling

Study [ref]	Design / sample	Key finding
Fernan et al. 2018 [9]	Between-subjects experiment (n = 274)	"Protein" in the product title raised perceived healthfulness, mediated by assumed higher fibre and iron; a "good source of protein" claim produced no such halo.
McKeon & Hallman 2024 [10]	Survey (n = 1,022), two real cereals	Protein-labelled cereal judged healthier despite more sugar and calories: 54.5% saw no sugar difference, 57.3% more likely to buy, 27.9% willing to pay a premium.
Li & Dando 2019 [11]	Sensory test, identical vanilla yogurts	A "high-protein" label raised liking scores; protein-attentive respondents felt less full, suggesting the label may encourage rather than restrain consumption.
Kim et al. 2026 [4]	Discrete choice experiment	Added-protein labels raise perceived healthfulness and lower perceived tastiness, yet still command a measurable willingness to pay.

Across these studies the label, rather than the nutrient, drives purchasing — the commercial incentive is to add protein claims whether or not they meet a real need [4].

Implications for vulnerable consumers

This evidence describes a "protein premium" in which the label, rather than the nutrient, drives purchasing, and the commercial incentive is to add protein claims whether or not the addition meets a real nutritional need [4]. The concern for respiratory medicine is that the populations most exposed to these claims include people making dietary decisions around chronic illness. A patient with COPD who selects a protein-fortified product on the strength of a front-of-package label may be acting on perceived rather than actual benefit, and may at the same time be increasing intake of sugar, calories, or, as Section 6 describes, contaminants. The marketing of protein to clinically vulnerable groups has not been studied directly, and that absence is itself notable given how heavily older and health-conscious consumers are represented in this market.

Protein, lung function, and respiratory health

Protein and respiratory muscle physiology

The diaphragm and accessory muscles of respiration are skeletal muscle, and like other skeletal muscle they depend on dietary protein for maintenance and repair. In COPD, protein-energy malnutrition contributes to the loss of respiratory and peripheral muscle mass, and nutritional depletion is an independent predictor of mortality [6]. The mechanistic basis for muscle loss in COPD is now reasonably well characterized: systemic inflammation, oxidative stress, hypoxia, hypercapnia, corticosteroid exposure, and an imbalance between protein synthesis and catabolism converge to reduce muscle mass and impair repair [12]. Because the synthesis-to-catabolism balance sits at the center of this cascade, protein intake is one of the few modifiable points of intervention, and clinical guidance has converged on intakes of 1.2 to 1.7 g/kg/day for respiratory muscle preservation in COPD [6,13].

Sarcopenia as the link between protein and the COPD course

Sarcopenia, the loss of muscle mass and function, is one of the most consequential extrapulmonary features of COPD, and it gives the protein question its clinical urgency. Prevalence estimates vary with setting and diagnostic criteria, ranging from about 15 percent in stable outpatients to as high as 67 percent in more severe or institutionalized populations [13,14]. A meta-analysis of 15 studies and 7,583 patients estimated an overall prevalence of 29 percent and found that COPD raised the odds of sarcopenia (odds ratio 1.51, 95% CI 1.19 to 1.92) [15]. The clinical stakes are high. In a longitudinal cohort, COPD patients with sarcopenia had markedly higher rates of acute exacerbation (84.6 versus 31.0 percent), all-cause mortality (30.8 versus 5.2 percent), and pneumonia, and sarcopenia was an independent predictor of exacerbation with a hazard ratio of 5.98 (95% CI 1.58 to 22.70) [7]. Management guidance consistently pairs resistance and aerobic exercise with protein-rich nutrition, leucine, and vitamin D, since pharmacological agents such as myostatin inhibitors and selective androgen receptor modulators remain experimental [13]. Because adequate protein intake is the primary dietary strategy for preventing and managing sarcopenia, these data provide the strongest argument for treating protein status as a clinical variable in COPD rather than a consumer preference [13,15].

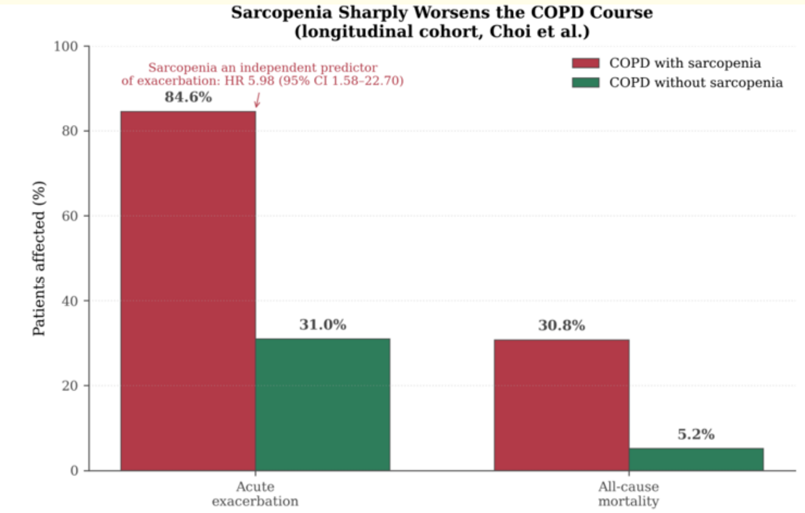

Figure 3

Protein and nutritional support in COPD: What the trials show

The trial evidence for protein and broader nutritional support in COPD is positive in direction but modest in certainty, and it deserves to be reported plainly. A meta-analysis of 13 randomized controlled trials (RCTs; n = 439) found that nutritional support produced greater gains in protein intake (14.8 g/day), energy intake (236 kcal/day), body weight (1.94 kg), and grip strength (5.3 percent) than control, with the functional benefits clearest in patients who were malnourished at baseline [16]. A larger and more recent meta-analysis of 32 RCTs (1,414 participants) confirmed improvements in body weight (mean difference 1.44 kg), lean mass, and handgrip strength with energy and protein supplementation, but graded the certainty of evidence as low to very low and judged most trials to carry some or high risk of bias [17]. When the question narrows to lung function and exercise capacity the picture is more mixed. A network meta-analysis of 48 RCTs (2,481 participants) ranked protein second only to nitrate for improving exercise capacity (cumulative ranking 68.6 percent) but found variable effects on FEV1 and the FEV1/FVC ratio across supplement types [18]. A systematic review of supplementation during pulmonary rehabilitation was more sobering still, reporting that most studies showed no added benefit over rehabilitation alone, with only one small trial of a protein-containing drink with omega-3 fatty acids and antioxidant vitamins showing a positive result [19]. Methodological heterogeneity, particularly the use of many different physical function tests, has repeatedly prevented firm conclusions and pooled analysis [19,20].

Two further lines of evidence sharpen the clinical rationale even where trial certainty is low. First, total protein status itself tracks disease severity: in a study of 84 patients, plasma total protein below 61.2 g/L was associated with severe COPD, and total protein predicted a high BODE index more accurately (area under the curve 0.789) than albumin or globulin alone [21]. Because that study was cross-sectional, it cannot separate cause from consequence, and low protein may be as much a marker of advanced, cachectic disease as a driver of it. Second, specific protein fractions may have effects beyond mass, as a whey-peptide drink reduced the inflammatory markers CRP, TNF-α, IL-6, and IL-8 after six weeks in one trial, hinting at an anti-inflammatory role for particular protein components, though the evidence remains preliminary [20]. The recurring caveat across this literature is the same one the consumer market ignores: benefit is most evident in those who are depleted, and the quality of evidence calls for adequately powered, protein-specific trials [17,19].

Table 3. Protein and nutritional-support evidence in COPD

Study [ref]	Design (n)	Main findings	Certainty
Collins et al. 2012 [16]	Meta-analysis, 13 RCTs (n = 439)	vs control: protein +14.8 g/day, energy +236 kcal/day, weight +1.94 kg, grip strength +5.3%; benefit clearest in the malnourished.	—
Bernardes et al. 2023 [17]	Meta-analysis, 32 RCTs (n = 1,414)	Energy/protein supplementation improved body weight (+1.44 kg), lean mass, and handgrip strength.	Low to very low
Zeng et al. 2025 [18]	Network meta-analysis, 48 RCTs (n = 2,481)	Protein ranked second only to nitrate for exercise capacity (SUCRA 68.6%); variable effects on FEV1 and FEV1/FVC.	—
Aldhahir et al. 2020 [19]	Systematic review (pulmonary rehabilitation)	Most studies showed no added benefit over rehabilitation alone; one small protein + omega-3 + antioxidant trial was positive.	—

The recurring caveat: benefit is most evident in the depleted, and evidence quality calls for adequately powered, protein-specific trials [17,19].

Protein in post-infectious pulmonary recovery

Protein intake also matters after acute respiratory illness, where the evidence has grown rapidly since 2020. The European Society for Clinical Nutrition and Metabolism recommended oral supplements providing at least 30 g of protein daily for patients with SARS-CoV-2 infection able to eat, and a target of 1.3 g/kg/day for those in intensive care [22]. Inadequate intake during recovery is common: among patients at a post-COVID clinic, 48 percent were at risk of malnutrition, only 3 percent met the recommended protein intake at every meal, and poorer intake tracked with persistent symptoms including breathlessness [23]. At the population level, an ecological analysis across 170 countries linked the supply of protein-rich foods, including eggs, fish, meat, and milk, to higher recovery rates, although the ecological design limits inference at the individual level [24]. Evidence for asthma, cystic fibrosis, and bronchiectasis is comparatively thin, and the developmental influence of prenatal protein on lung growth, while biologically plausible, rests largely on the indirect data discussed in the next section.

Protein, immune modulation, and respiratory defense

Amino acids and the machinery of immune defense

The link between protein and immunity is direct at the molecular level, because immune cells and their products are themselves built from amino acids. Dietary protein deficiency lowers plasma amino acid concentrations and impairs immune function, a problem that persists not only in low-income settings but among the elderly and hospitalized populations of wealthy countries [25]. Specific amino acids carry defined roles: glutamine supports lymphocyte proliferation and macrophage nitric oxide synthesis, arginine is the precursor for the nitric oxide central to antimicrobial defense, and the branched-chain amino acids regulate immune-cell protein synthesis through mTOR signaling [25]. Both antibody production and the proliferation of immune cells depend on adequate amino acid availability, which is why protein status influences the mucosal barrier function of the respiratory tract and the capacity to mount and sustain a response to airway pathogens [25,26].

From intake to infection outcomes

Evidence that protein intake changes clinical respiratory outcomes, rather than only laboratory measures, is strongest in two settings. In elite cyclists, raising protein intake to 3 g/kg/day restored the CD8+ T-lymphocyte trafficking impaired by intensified training and reduced the incidence of upper respiratory tract infection compared with a moderate intake of 1.5 g/kg/day [27]. The relevance to chronic respiratory disease lies in the parallel between exercise-induced immune suppression and the immune dysfunction of COPD, where systemic inflammation and deconditioning impair the same cell-trafficking mechanisms [27]. During the COVID-19 pandemic, reviews converged on the conclusion that insufficient energy and protein intake suppress immune function and raise infection susceptibility [28]. Composite measures point the same way from the clinical side: a low prognostic nutritional index, which combines serum albumin with lymphocyte count, independently predicted mortality in hospitalized COVID-19 patients [29]. That index should be read with caution, because serum albumin falls during systemic inflammation independently of intake, so a low value can reflect illness severity as much as nutritional depletion.

The gut-lung axis

A less obvious route connects dietary protein to the lung through the gut. The gut and respiratory tract communicate bidirectionally through what is now termed the gut-lung axis, and dysbiosis in the gut has been linked to asthma, COPD, and respiratory infection [30]. Gut-derived metabolites, particularly the short-chain fatty acids produced by microbial fermentation, reach the lung through the systemic circulation and modulate pulmonary immune responses [30]. Diet shapes this axis, as a high-fiber diet has been shown to protect against influenza by altering bone-marrow hematopoiesis and enhancing CD8+ T-cell metabolism, while disruption of the gut microbiota worsens viral respiratory infection [31]. Because the type and quantity of dietary protein influence microbial composition and metabolite production, protein is plausibly one of the dietary inputs to respiratory immune competence through this pathway, although protein-specific effects on the gut-lung axis have not yet been isolated [32]. Maternal nutrition appears to act through related immune programming, with inadequate intake during gestation associated with greater infant susceptibility to respiratory infection and asthma [33].

Contaminants in protein products and respiratory risk

Heavy metals in protein supplements

The same products marketed for health carry a measurable contaminant burden, and the pattern of contamination is now well documented. A formal risk assessment using United States Environmental Protection Agency reference doses calculated hazard quotients below 1.0 for arsenic, cadmium, mercury, and lead at typical consumption, which suggests that non-carcinogenic risk is unlikely for average users; the same analysis found that United States Pharmacopeia limits were exceeded at three servings per day, and that plant-based powders carried consistently higher cadmium and lead than animal-based products [34]. Independent testing has reinforced both findings. A 2025 investigation of 23 products reported that about 70 percent exceeded a conservative daily lead threshold, with plant-based proteins averaging roughly nine times the lead of dairy proteins [35]. An earlier program that tested 134 products found detectable heavy metals in nearly all of them, with plant-based and organic products performing worst because crops take up metals from soil [36]. A European market analysis reached broadly reassuring conclusions for the specific products tested but emphasized that compliance with heavy-metal limits is voluntary for dietary supplements, which leaves a structural regulatory gap [37]. Across these studies the consistent signal is that contamination is real, that plant-based proteins concentrate it, and that heavy users face the greatest cumulative exposure.

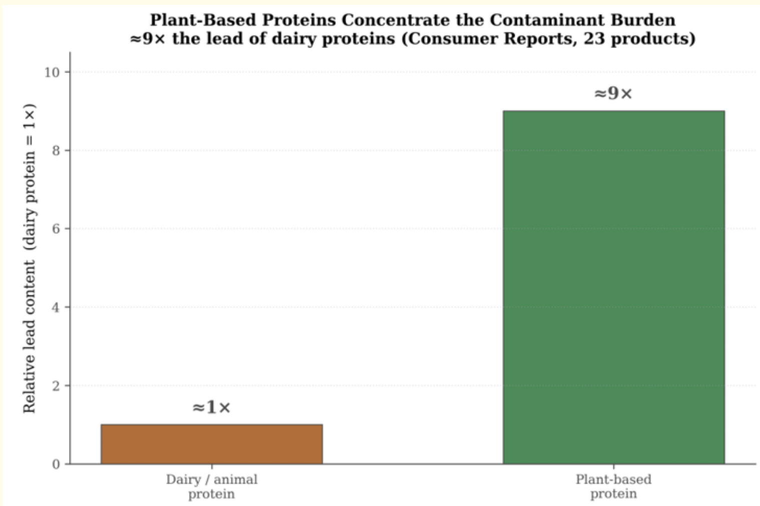

Figure 4

Table 4. Heavy-metal contamination in protein products

Study [ref]	Sample tested	Finding
Bandara et al. 2020 [34]	Risk assessment using US EPA reference doses	Hazard quotients < 1.0 for arsenic, cadmium, mercury, lead at typical intake; US Pharmacopeia limits exceeded at 3 servings/day; plant-based higher in cadmium and lead.
Consumer Reports 2025 [35]	23 products	About 70% exceeded a conservative daily lead threshold; plant-based proteins averaged roughly nine times the lead of dairy proteins.
Consumer Reports 2018 [36]	134 products	Detectable heavy metals in nearly all; plant-based and organic products performed worst because crops take up metals from soil.
Horvath et al. 2025 [37]	Hungarian market analysis	Reassuring for the specific products tested, but heavy-metal compliance is voluntary for dietary supplements — a structural regulatory gap.

Cadmium is the contaminant of greatest respiratory concern: biological half-life 16–30 years, with a long toxicological record tying chronic exposure to impaired lung function and emphysema [38,39,41].

Why contaminant exposure is a respiratory concern

The respiratory relevance of these contaminants rests on a long toxicological record, particularly for cadmium, whose biological half-life in humans is 16 to 30 years [38]. Occupational work established the foundation, as among copper-cadmium alloy workers lung function abnormality and radiographic emphysema increased with cumulative cadmium exposure, with no clear threshold [39]. Community studies extended the finding to lower exposures, where higher urinary cadmium predicted lower FEV1 and a lower FEV1/FVC ratio independent of smoking [40]. A systematic review and meta-analysis found a significant association between cadmium exposure and COPD risk, supported by mechanistic work showing that cadmium triggers oxidative stress, ferroptosis, and NLRP3 inflammasome activation in lung epithelium, and that early-life exposure increases susceptibility to allergic asthma [41]. Animal models confirm that inhaled cadmium and lead produce a mixed picture of emphysema and fibrosis with immune-mediated remodeling [42], and cadmium accumulating in the lung impairs the innate immune defenses that protect against infection [38]. Two limitations temper how far this evidence reaches. Most of it concerns inhaled or occupational cadmium, which deposits directly in lung tissue, whereas supplement exposure is oral, with low intestinal absorption and accumulation that is mainly renal, so the lung dose from ingestion is not equivalent. The formal ingestion risk assessment cited above, moreover, placed hazard quotients below one at typical intake [34]. The respiratory concern is therefore better stated as a hypothesis than an established harm: a chronic, additive, low-level exposure, retained for decades, that is plausibly relevant for heavy or long-term users and for those with pre-existing lung disease, but that has not been quantified for the oral route against human respiratory endpoints.

Research gaps and future directions

Knowledge gaps

Several gaps follow directly from the evidence reviewed here. The most basic is the absence of longitudinal studies linking protein supplement use to pulmonary outcomes; the clinical literature establishes that protein status matters in COPD and post-infectious recovery, but no cohort has tracked regular supplement consumers for respiratory endpoints. Trial evidence for protein in respiratory disease is similarly limited, with most studies underpowered, heterogeneous in their outcome measures, and graded at low certainty [17,19]. The economics are unstudied at the relevant intersection, as there is no integrated analysis connecting the cost of protein fortification to potential savings in respiratory care, and even basic source-by-source ingredient pricing is poorly represented in the peer-reviewed literature [5]. A disconnect runs through the whole review: the trials showing respiratory benefit used medically supervised oral nutritional supplements and food fortification in malnourished patients, not the commercial protein powders and fortified snacks that drive the consumer market, so it remains unproven that the products people actually buy reach, or help, the respiratory patients who might benefit. Contaminant exposure, for its part, has been quantified in products but not in people, which leaves the actual body burden of regular consumers, and its respiratory consequences, unmeasured [34,37].

Future research priorities

These gaps suggest a concrete agenda. Adequately powered randomized trials should test protein-enriched diets in COPD and in post-COVID pulmonary rehabilitation, using standardized functional and lung-function endpoints to overcome the heterogeneity that has frustrated synthesis [18,19]. Pharmacoeconomic analyses should evaluate protein supplementation as a respiratory-care intervention rather than a general nutrition product. Respiratory-specific protein intake guidelines, addressing both adequacy and the safety of supplement sources, would give clinicians something the consumer market does not provide. Longitudinal biomonitoring of heavy-metal accumulation in regular protein consumers, stratified by plant and animal source, would close the loop between product testing and human risk.

Conclusion

Protein occupies an unusual position in respiratory health, valued as a consumer good and underused as a clinical tool, and this review has tried to hold both facts in view at once. The commercial case for protein fortification is strong and the market is expanding quickly, yet the economic evidence that supports fortification as public health policy concerns micronutrients in deficient populations, not premium protein sold to the well-nourished [5]. The clinical evidence, for its part, supports adequate protein intake for preserving respiratory muscle, managing the sarcopenia that drives COPD exacerbations and mortality, and sustaining immune defense during respiratory infection, even though the trial base remains modest in quality [7,15,17]. Set against these benefits is a genuine and consistently documented safety concern, since the contaminant load of protein products, cadmium in particular, intersects with a toxicological record tying chronic exposure to impaired lung function and emphysema [34,39,41].

For pulmonary practice the practical implication is modest but real. Clinicians have reason to ask patients about protein supplement use, both to identify those who would benefit from improved intake and to recognize those whose consumption pattern raises a contaminant concern. The larger opportunity is cross-disciplinary, drawing nutrition science, pulmonary medicine, and food-safety regulation toward shared questions that none of them currently owns. Protein-fortified foods and supplements are now a fixed feature of how people eat, and the respiratory consequences of that fact, both helpful and harmful, deserve more attention than they have so far received.

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