Observational Study

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Citizens protein project

A self-funded, transparent, and concerning report on analysis of popular protein supplements sold in the Indian market

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Abstract

Protein powders, including those containing herbal and dietary supplements such as vitamins, minerals, and other natural or synthetic ingredients, can be associated with hepatotoxicity. Protein supplements are often mislabeled and deceptive in their contents. In this self-funded transparent study, we extensively analyzed popular protein supplements in India to identify potential hepatotoxic substances based on industrial standards. All products underwent extensive analysis, including total protein content, fungal aflatoxin detection, pesticide residue estimation, heavy metal quantification, steroid detection, and complete organic and inorganic profiling, according to industry standards. Most protein supplements did not meet the labeled and advertised protein content, while certain brands surpassed the stated levels, raising concerns about potential "protein/amino-spiking." In addition, the major brands contained detectable fungal toxins and pesticide residues. Furthermore, many major formulations contained harmful heavy metals such as lead and arsenic, and some featured hepatoxic herbal extracts, particularly green tea extract, turmeric, Garcinia cambogia, and Ashwagandha. Indian-made products were inferior to those manufactured by multinational companies. The presence of various potentially toxic compounds, such as cycloheptatriene, benzene derivatives, toluene, and isopropyl alcohol, within a nonstandardized and unregulated diverse ingredient mix added to the overall concern. We demonstrate that the protein-based herbal and dietary supplement industry requires stringent scrutiny, regulation, and basic safety studies before being marketed. Manufacturers must consider reducing "ingredient complexities" of their protein powders to prevent adverse interactions between herbal and nonherbal components in consumers. Manufacturers must avoid using known toxic ingredients to reduce the avoidable disease burden within the public community.

Abbreviations: FSSAI = Food Safety and Standards Authority of India, GC-MS = gas chromatography and mass spectrometry, HDS = herbal and dietary supplements.

Keywords: drug-induced liver injury, hepatotoxicity, herbal and dietary supplements, protein powder, whey protein

1. Introduction

Dietary food supplements, in the form of animal-, dairy-, or plant-based protein formulations, are commonly used by habitually active persons, athletes, body builders, and specific patient groups. Additionally, protein supplements are used in weight loss protocols and as part of a protein-deficient diet. Herbal and dietary supplements (HDS), including protein-based formulations with or without added botanical ingredients, vitamins, minerals, amino acids, and other natural or synthetic products, are a growing concern for hepatotoxicity and are associated with liver injury, failure, and death.[1] A recent study showed that the contents of HDS implicated in liver injury in the United States are frequently mislabeled.[2] Analysis of complementary and alternative medicine products revealed adulterants and contaminants associated with a lack of good manufacturing practices.[3] Analysis of complementary and alternative medicine products sampled from online and offline stores in the United States revealed the presence

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Because this study did not involve human participants, Rajagiri Hospital's institutional review board determined that approval was not required.

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of toxic metals.[4] Similar to the United States Food and Drug Administration, the Food Safety and Standards Authority of India (FSSAI) does not approve HDS but regulates good manufacturing practices. The safety of contents in protein-based HDS must be assured by the manufacturer, while the content and labeling are scrutinized by the FSSAI, based on test results submitted by the manufacturer, that are not made public and remain nontransparent.[5] Nonetheless, protein supplements remain mislabeled, contents deceptive, advertisements misleading, and quality unclear. In the current published literature, there is dearth of transparent data on protein supplement quality analysis from a proactive healthcare perspective. Furthermore, the large body of published evidence on protein-based HDS-related liver toxicity lacks qualitative product analysis. We aimed to analyze popularly sold protein products through standardized and validated methodology, to provide transparency with regards to content, labeling, adulteration, and contamination. The importance of our study is that it is unique, pro-public, and self-funded, to identify potential toxic ingredients. We performed an exhaustive protein-quantitative, product-qualitative, and chemical and toxicology analysis based on industrial standards, on popular brands of protein supplements sold in the Indian market.

2. Methods

2.1. Product purchase and preparation

Over the course of 2 months, we exhaustively reviewed online supplement stores and visited local, large-scale, authorized protein supplement wholesale and retail sellers in our city to prepare a list of popular and highest-selling pure proteins as well as protein-based HDS. Once the list was formulated, the products were purchased directly from manufacturer stores (online or offline) and authorized dealers. Where applicable, the authenticity of products was confirmed using the QR code instructions. A designated person, blinded to the project aims and objectives, was independently directed to prepare a master chart (Document 1, Supplemental Digital Content, http://links.lww.com/MD/M105) of the purchased products, which included the name of the product, product image, listing, and image of disclosed ingredients, nutritional information, disclosed protein per 100 g serving, batch number, manufacturing date, and expiry information. After preparation of the master chart, each product was numbered, and all identifying information was removed from the product covering. The blinded, number-coded products (Fig. 1) were then sent to an independent, FSSAI-approved, authorized food and drug testing laboratory (Neogen Corporation, Neogen Food and Animal Security Pvt. Ltd., Kochi, Kerala, India) to maintain a reasonable chain of command. Once the products were received at the analytical laboratory, they were opened under standard operating protocol-based conditions, and the powder samples were transferred to sterile containers and marked with the product code in the context of each analysis. After transfer, the samples were tightly closed and stored under ambient conditions until the analyses were completed. Because this study did not involve human participants, Rajagiri Hospital's institutional review board determined that ethical approval was not necessary.

2.2. Protocols for blinded product analyses

All products were subjected to the analysis of total protein content (Kjeldahl method),[6] detection and quantification of fungal aflatoxin (high-pressure liquid chromatography and fluorescence detection),[7] pesticide residue detection and estimation (gas and liquid chromatography and tandem mass spectrometry),[8] detection and quantification of heavy metals (arsenic, cadmium, lead, mercury, thalium, and copper by inductively coupled plasma mass spectrometry),[9] steroid detection (gas chromatography-mass spectrometry using HP-5ms column),[10] and complete profiling of organic and inorganic contents (gas chromatography coupled to mass spectrometry). The quality control measures implemented during the analyses, including internal standards, calibration checks, and validation protocols were as per rules and guidelines laid by industry standards and approved by government regulations. The detailed analytical methodology is presented in Document 2, Supplemental Digital Content, http://links.lww.com/MD/M106. The study adhered to all pertinent regulatory standards or guidelines for product testing, particularly relating to food and drug safety regulations.

3. Results

A total of 36 protein supplements were procured and analyzed. Seals were maintained on all procured products, coded, and blinded by independent personnel until their receipt in the analytical laboratory. Seals were broken, and the products were opened for analysis under standard operating conditions in the laboratory. Once the analysis was complete, the raw data and results were shared with the principal investigator (CAP) and coauthors (AHT and RR), who were thereafter unblinded to the samples using the original product and code master chart prepared initially by the third-party personnel. The unblinding was a simple match the product code to designated coded analytical output. The principal investigator and coauthors in the absence of the funder, further collated, and prepared the final summary of the results.

The purchased protein powders were of the following types: blended, pure plant-based, and pure whey-based formulations. The blends included either different blends of proteins or those with herbal extracts. Of the 14 blended formulations, 7 contained herbal extracts, and the rest included various types of protein sources, such as pea, soy, egg, milk (whole, whey, or casein), and peanuts. Four products were purely plant based in nature, and 18 powders were purely whey-based and whey-blended (concentrate, hydrolysate, and isolate). Twenty products were made in India, and the rest were manufactured by multinational companies.

Of 36 products, 9 had <40% detected protein content, while the rest had above 60%. Overall, 25 protein supplements (69.4%) were mislabeled about protein content; that is, the protein content per 100 g detected in analysis was less than what was advertised on the product, featuring <10% to more than 50% deficit. Two products from 1 manufacturer had 62% and 50.4% lower protein content while a commonly prescribed protein from a well reputed company also mislabeled protein content of approximately 30% deficit than advertised (Fig. S1, Supplemental Digital Content, http://links.lww.com/MD/M109). Certain protein brands were found to contain more than the labeled protein content in the quantification analysis. Higher protein content could suggest either good quality protein sources used in manufacturing or it could also be part of "protein or amino spiking" where supplement manufacturers intentionally add cheaper protein components such as cheaply available amino acids glycine and taurine to deceptively showcase higher protein content.

On fungal toxin analysis, 5 out of 36 (13.9%) samples were found to be contaminated with aflatoxins. In both samples, the aflatoxin content was above 10 µg/kg.

In pesticide residue analysis, 3 samples (8.3%) were found to be contaminated by trace amounts. One product contained fenobucarb (0.061 mg/kg), whereas the other contained thiamethoxam (0.017 mg/kg). The third product was contaminated with 2 types of pesticide residues: azoxystrobin (0.022 mg/kg) and dimethomorph (0.013 mg/kg).

Heavy metal analysis revealed that none of the protein powder contained mercury or thallium. Trace levels of arsenic were

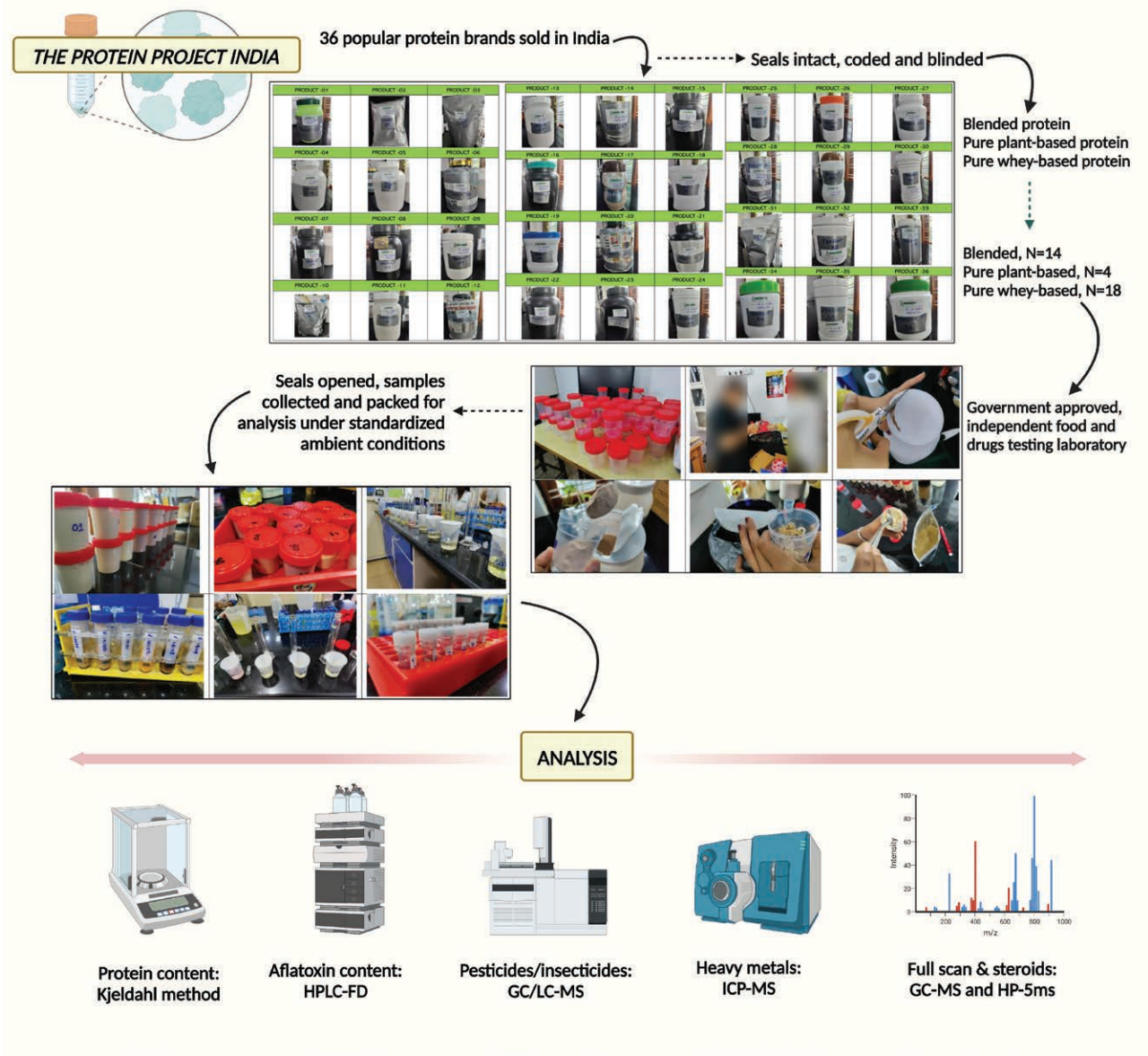

Figure 1. Summary of inclusion, protocols, and industry-based standards of methodical analysis of protein powders. GC/LC-MS = gas and liquid chromatography and tandem mass spectrometry, GC-MS, HP-5ms = gas chromatography-mass spectrometry using HP-5ms column, HPLC-FD = high-pressure liquid chromatography and fluorescence detection, ICP-MS = inductively coupled plasma mass spectrometry.

detected in 5 (13.9%), cadmium in 10 (27.8%), lead in 27 (75%), and copper in 34 (94.4%) samples. Copper, as a trace mineral, is routinely a component of the added and disclosed ingredients in dietary supplements. Nonetheless, none of the products had a uniform or standard quantity of copper inclusion (minimum 1.49 mg/kg to maximum 30.61 mg/kg), even though the recommended daily intake of copper is 900 µg/day in the adult population.

Interestingly, the lowest protein content, both advertised and detected, was mostly found among protein brands that were heavily promoted or commonly prescribed. Aflatoxins have been detected mostly in plant-based protein supplements. Pesticide residues were also detected only in plant-based protein supplements and not in pure dairy-based or blended dairy supplements. A detailed summary of the tested protein supplements and findings on protein content, mycotoxins, pesticide residues, and heavy metals are shown in Table 1.

A detailed review of the ingredients disclosed in the protein supplements revealed that some of them contain well-documented and inherent hepatotoxic herbal ingredients. The Himalayan Organics Protein Super Herbs contained green tea extract, curcumin, and garcinia cambogia; Nutrela® Whey Protein contained 14 herbal extracts, including ashwagandha; Quista Pro Himalaya® Whey protein contained ashwagandha and Cissus quandrangularis extracts; Elements® protein powder did not disclose type of protein, but mentioned 5 types of herbal extracts only on the label; Herbalife® Formular 1 Nutritional Shake contained turmeric extract and Oziva® Protein and Herbs containing a blend of 7 herbs, including ashwagandha, which was also present in Dr Vaidya's® Weight Plus containing a blend of 6 herbs along with dairy-based protein (Document 1, Supplemental Digital Content, http://links.lww.com/MD/M105).

Compared to multinational manufacturing brands, Indian protein brands were of lower quality, associated with higher chances of contamination and poor manufacturing practices, and were at risk of including multiple liver toxic ingredients, mostly in the form of herbal blends. Briefly, 16 (64%) brands out of 25 that had mislabeled protein content were made by India-based manufacturers; 4 (80%) out of 5 products with trace arsenic were from Indian companies, and presence of lead

Table 1

Summary of protein supplements analysis protein content, mycotoxins, pesticide residue, and heavy metal estimation.

Code	Protein (%)	Aflatoxin (µg/kg)	Pesticides (mg/kg)	Heavy metals (mg/kg)					
				As	Cd	Pb	Hg	Tl	Cu
1	65.65	BLQ	BLQ	BLQ	BLQ	0.086	BLQ	BLQ	1.61
2	43.28	BLQ	BLQ	BLQ	BLQ	0.04	BLQ	BLQ	4.41
3	58.17	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	1.51
4	63.93	BLQ	BLQ	BLQ	BLQ	0.038	BLQ	BLQ	2.94
5	73.34	BLQ	BLQ	BLQ	0.029	BLQ	BLQ	BLQ	2.87
6	68.37	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	1.92
7	76.11	BLQ	BLQ	BLQ	0.043	BLQ	BLQ	BLQ	3.65
8	71.65	BLQ	BLQ	BLQ	0.047	BLQ	BLQ	BLQ	4.43
9	63.63	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	4.57
10	50.65	2.93	BLQ	0.048	BLQ	0.033	BLQ	BLQ	30.61
11	73.16	BLQ	BLQ	BLQ	0.028	0.028	BLQ	BLQ	11.66
12	71.71	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	2.38
13	80.34	BLQ	BLQ	BLQ	BLQ	0.29	BLQ	BLQ	BLQ
14	34.22	BLQ	BLQ	0.063	BLQ	BLQ	BLQ	BLQ	5.34
15	80.72	7.51	BLQ	BLQ	BLQ	0.04	BLQ	BLQ	1.49
16	65.19	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	2.97
17	10.41	2.25	BLQ	BLQ	0.026	0.1	BLQ	BLQ	2.19
18	48.45	BLQ	BLQ	BLQ	BLQ	0.071	BLQ	BLQ	BLQ
19	19.59	BLQ	BLQ	BLQ	BLQ	0.1	BLQ	BLQ	6.60
20	46.29	BLQ	BLQ	BLQ	BLQ	0.19	BLQ	BLQ	3.76
21	76.96	BLQ	BLQ	BLQ	BLQ	0.11	BLQ	BLQ	2.40
22	75.80	BLQ	BLQ	BLQ	BLQ	0.29	BLQ	BLQ	2.97
23	68.59	BLQ	BLQ	BLQ	BLQ	0.3	BLQ	BLQ	2.19
24	26.13	BLQ	BLQ	BLQ	BLQ	0.27	BLQ	BLQ	BLQ
25	19.41	BLQ	*	BLQ	0.042	0.31	BLQ	BLQ	5.73
26	68.58	BLQ	BLQ	BLQ	BLQ	0.25	BLQ	BLQ	3.29
27	33.42	BLQ	BLQ	0.075	0.037	0.32	BLQ	BLQ	4.48
28	79.00	BLQ	BLQ	0.085	BLQ	0.23	BLQ	BLQ	9.34
29	7.99	BLQ	BLQ	0.031	BLQ	0.26	BLQ	BLQ	16.80
30	76.44	15.56	BLQ	BLQ	0.026	0.28	BLQ	BLQ	8.80
31	71.04	BLQ	BLQ	BLQ	BLQ	0.23	BLQ	BLQ	1.49
32	84.50	BLQ	BLQ	BLQ	0.029	0.26	BLQ	BLQ	11.27
33	35.67	BLQ	BLQ	BLQ	BLQ	0.23	BLQ	BLQ	20.80
34	65.49	BLQ	†	BLQ	BLQ	0.27	BLQ	BLQ	1.71
35	20.52	BLQ	‡	BLQ	BLQ	0.22	BLQ	BLQ	5.33
36	84.69	13.15	BLQ	BLQ	0.03	0.23	BLQ	BLQ	10.83

LOQ for pesticide 0.01 mg/kg, LOQ for heavy metal 0.025 mg/kg, LOQ for aflatoxin 1.5 µg/kg.

As = arsenic, BLQ = below limit of quantification, Cd = cadmium, Cu = copper, Hg = mercury, LOQ = limit of quantification, Pb = lead, Tl = thallium.

*Fenobucarb: 0.061 mg/kg.

†Azoxystrobin: 0.033 mg/kg, dimethomorph: 0.013 mg/kg.

‡Thiamethoxam: 0.017 mg/kg.

and very high levels of copper were also found predominantly among India-based and manufactured protein products.

A complete gas chromatography and mass spectrometry (GC-MS) scan identified multiple organic and inorganic compounds that were clinically significant in the context of health- and disease-related events. The most detected compounds that featured in 30 (83.3%) analyzed products included cycloheptatriene, spiroheptadiene, and acetone, followed by acetic acid in 28 (77.8%), dichloromethane in 27 (75%), ammonium acetate, toluene and trichloromethane in 26 (72.2%) protein formulations. Furthermore, isopropyl alcohol and hydrogen isocyanate were also found in 19 (52.8%) and 18 (50%) products, respectively. A wide variety of other types of industrial solvents, such as alcohols, phenols, aldehydes, ketones, and esters, were notable in this analysis. None of the products contained synthetic steroids or hormonal agents, even though the plant-based formulations contained identifiable natural phytosteroids. Thus, GC-MS revealed the broad and chaotic heterogeneity of the components present in various types of protein supplements. The complete analytical output featuring all significant (>70% match factor) identified components in the protein formulations is shown in Document 3, Supplemental Digital Content, http://links.lww.com/MD/M107.

4. Discussion

This self-funded transparent report on popular protein brands sold in the Indian market revealed interesting, intriguing, and concerning findings: the majority of protein supplements did not contain labeled and advertised protein content; certain brands contained more than the labeled or advertised protein content, raising concerns of "protein/amino-spiking"; fungal toxins and pesticide residues were identifiable even in supposedly "good" brands; heavy metals that negatively impact human health such as lead and arsenic were found within many major formulations; and the presence of broad types of potentially toxic compounds such as industrial solvents and volatile organic compounds within a nonstandardized and heterogenous ingredient milieu (Fig. 2).

Researchers in Spain checked the percentage of protein declared on supplement labeling as well as the levels of various metals and minerals using a methodology like that described in our paper. They observed statistically significant differences between the declared and real protein percentages and concluded that the quality and safety of these products need to be monitored and regulated because a high degree of noncompliance with labeling claims was detected, echoing our findings.[11] A recent study highlighted that a large proportion of

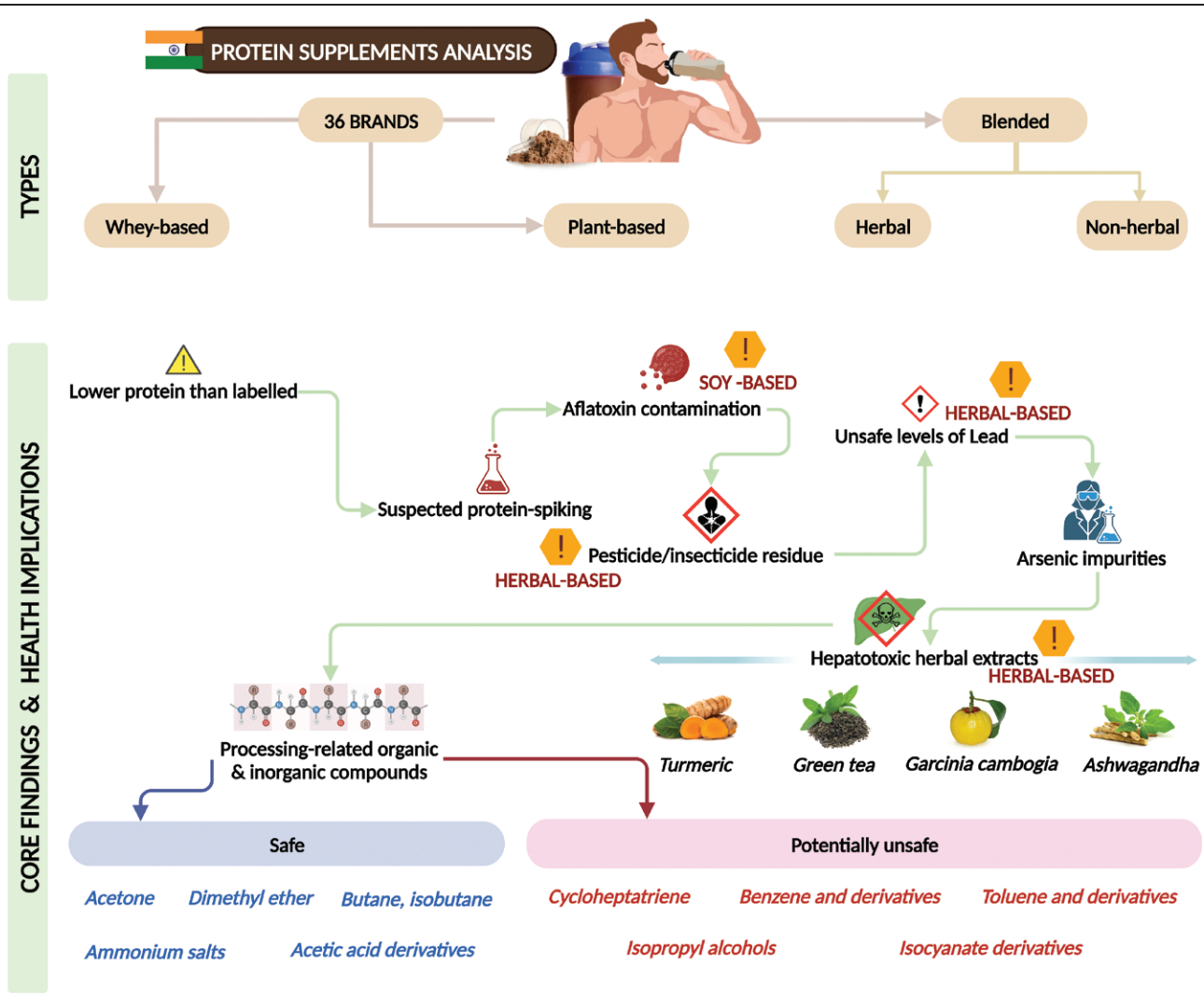

Figure 2. Summary of significant findings from the Citizens Protein Project.

commercially available herbal, protein, and dietary supplements implicated in liver injury were frequently mislabeled, similar to our study findings.[2]

Aflatoxins are fungal toxins that have mutagenic and carcinogenic (liver related) effects. In our study, we identified aflatoxins in 4 products, all of which were plant-based proteins, among which 3 were soy based and 1 was a multiherbal containing hyacinth bean. In the 2 products, aflatoxin levels were very high. Soy products are known to be naturally contaminated with mycotoxins, whereas multiherbal products are known to contain fungal toxins.[12–14] Consumers must be aware of protein sources, especially plant (bean)-based sources, linked to natural contamination with mycotoxins that could negatively impact health outcomes.

The carbamate insecticide fenobucarb was identified in 1 product and above the safety limits as set by the FSSAI (0.01 mg/kg safe limit, identified 0.061 mg/kg) while the neonicotinoid insecticide, thiamethoxam (0.017 mg/kg) was well within limits as prescribed by the regulatory body (0.05 mg/kg in milk/milk products and 0.02–0.03 mg/kg in plant products). A third product was contaminated with 2 types of pesticide residue, namely, azoxystrobin (0.022 mg/kg) and dimethomorph (0.013 mg/kg) both of which were above the advised safe limits (0.01 mg/kg) and not allowed (safe limits mentioned in fruits and tubers only) in fully processed protein-based products respectively.[15] Higher than the safe limits of pesticide and insecticide residues in food products are associated with multiple adverse health outcomes, such as neurological and reproductive disorders, hormonal disruptions and respiratory conditions, renal and liver damage, and malignancy.[16]

The presence of arsenic and lead contamination in most of the analyzed protein products in our study is of grave concern. Both arsenic and lead exposure, even at low levels, impact human health in the form of an increased risk of cancer, blood disorders, gastrointestinal diseases, impaired brain development and functioning, and kidney and liver damage. The World Health Organization states that there is no safe level of Pb exposure. The finding that most protein supplements in our study were contaminated with lead residue was concerning.[17–19] Similarly, the recommended daily intake of Cu in adults is 900 µg/day. A copper intake of more than 30 g/day was associated with acute liver injury and liver failure. For example, in one of the protein products analyzed, the copper content was 33 times higher than the recommended limits (0.9 mg/day vs 3 mg/100 g) concerning for negative health outcomes and the prolonged and the consistent use of such requires caution and prudence.[20]

Herb-blended protein supplements containing hepatotoxic herbs were another health concern that was particularly notable among formulations made by Indian manufacturers. Green tea extract is a well-known hepatotoxic agent in which liver injury is idiosyncratic, mediated by immune mechanisms, and with risks associated with HLA-B*35:01 predisposition.[21,22] Turmeric-based dietary supplements are an increasingly concerning cause of severe liver injury and liver failure worldwide,

especially in the West, so much so that the Italian Health Regulatory body prohibited all health claims linked to turmeric and issued warning labels for turmeric-containing health supplements.[23,24] Garcinia cambogia and Malabar tamarind have been consistently associated with liver injury and liver failure, sometimes leading to death or liver transplantation due to the presence of hydroxycitric acid. Products containing Malabar tamarind extracts have been banned by the United States Food and Drugs Administration in the context of consumer safety.[25–27] Finally, another important and upcoming cause of liver injury globally is the Ashwagandha herb. Studies from the USA and multiple reports from Europe, as well as a recently published large series from India, have shown that Ashwagandha use can be associated with severe cholestatic hepatitis, which is usually self-limiting but can prove fatal in those with preexisting liver disease.[28,29]

GC-MS analysis revealed that one of the most common organic compounds identified in the majority of the processed protein products was 1,3,5-cycloheptatriene. Cycloheptatriene is a breakdown derivative of tropane alkaloids, the latter of which are found mostly in various plants, some of which are inherently toxic. The presence of tropane derivatives in processed food products is well known and is due to contamination during manufacturing and processing.[30] Nonetheless, the impact of cycloheptatriene on human health and disease promotion with oral intake remains unknown, even though they are considered highly toxic in the context of the respiratory, eye, and skin systems.[31] Various other compounds identified, such as acetone, butane, isobutane, dimethyl ether, acetic acid, and ammonium derivatives, are generally considered safe with low potential for toxicity and are leached contaminants that occur during processing and packing. Nonetheless, benzene derivatives, toluene, isopropyl alcohol, and hydrogen isocyanate have been documented to have various negative health outcomes, including liver and renal toxicities, and the cumulative harm from regular use of protein supplements with such compounds warrants study and surveillance.[32–34] Our study with transparent results aimed at educating the public at large comes at the right time when the Government of India recently proclaimed that over 40,000 cases, both civil and criminal, were filed against various nutraceutical companies that manufacture and sell protein and dietary supplements that were found unsafe for human consumption and did not meet food safety standards.[35]

Our study has several limitations. The Kjeldahl method is the industry standard for quantifying proteins, but the result is based on nitrogen content, which approximates the nitrogen attributable to protein. Optical or mid-infrared spectroscopy augments standard methods for identifying the doping of products with proteins or cheaper amino acids such as taurine, glutamate, aspartate, or lysine. In those protein supplements that had higher than labeled protein content per 100 g, we did not perform a specific analysis to confirm protein/amino-spiking. For example, the highest relative protein percentage in our study was identified in the Muscletech Nitrotech Whey. In November 2015, a massive lawsuit was settled by Muscletech® regarding the extensive line of protein powders that were spiked with amino acids. The protein content listed on the "nutrition facts" label was much greater than the actual amount of food-based protein contained in the products.[36] Even though the labels revealed the presence of hepatotoxic herbal components, we did not confirm the presence of these herbal extracts in further analysis. The GC-MS scan revealed a multitude of organic and inorganic compounds that were not quantified, and their detection was made on match-factor analysis and not via quantification methods, which could mean that there were false positives and negatives among the reported compounds. Nonetheless, the GC-MC whole scan and match-factor-based identification of compounds are standardized methods and provide rational and reasonable estimates of the quality of the product under analysis. We could not authenticate and quantify all ingredients mentioned in the labels of the respective protein supplements; therefore, the actual type(s) of labeled protein(s), minerals, botanicals, and dietary supplement additives present in the product were not verified. The study has generalized about the quality and safety of Indian protein brands compared to multinational manufacturers. Our findings require validation from detailed comparative analyses as there may be concerns about generalizations based on limited data.

Our self-funded report on popular protein brands in the Indian market revealed that many supplements did not have the labeled protein content; some brands had suspected protein spiking and reputable brands contained fungal toxins, pesticide residues, heavy metals such as lead and arsenic, and potentially toxic organic and inorganic compounds, specifically those manufactured by India-based companies. Protein supplements containing hepatotoxic herbs, such as green tea extract, turmeric, Garcinia cambogia, and Ashwagandha, were particularly worrisome. Additionally, compounds found in some supplements, such as cycloheptatriene, benzene derivatives, toluene, and isopropyl alcohol, warrant further study because of their documented negative health effects.

Author contributions

Conceptualization: Cyriac Abby Philips.
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Visualization: Cyriac Abby Philips.
Writing – original draft: Cyriac Abby Philips.
Writing – review & editing: Arif Hussain Theruvath, Resmi Ravindran, Paras Chopra.

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