

LONG-TERM NUTRITION TRANSITION IN KARNATAKA: RURAL–URBAN CHANGES IN MACRONUTRIENT INTAKE AND FOOD SOURCES

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ABSTRACT

The study examined long-term changes in estimated household macronutrient and energy intake in rural and urban Karnataka, India, from 1993–94 to 2023–24. Successive National Sample Survey rounds and the Household Consumption Expenditure Survey were harmonised to estimate daily per-capita carbohydrate, protein, fat, and energy intake and to compare the five leading food sources of each macronutrient in 1993–94 and 2023–24. In rural Karnataka, carbohydrate intake declined from 391.02 to 333.79 g/person/day, whereas protein rose from 52.62 to 60.68 g/person/day, fat from 24.82 to 65.06 g/person/day, and energy from 1,997.93 to 2,163.38 kcal/person/day. In urban Karnataka, carbohydrate declined from 352.09 to 334.82 g/person/day, while protein rose from 49.63 to 63.60 g/person/day, fat from 33.21 to 70.96 g/person/day, and energy from 1,905.75 to 2,232.28 kcal/person/day. In 2023–24, protein, fat, and energy intake were significantly higher in urban than in rural households ($p < 0.001$), whereas carbohydrate intake did not differ significantly ($p = 0.601$). Rice remained a major carbohydrate and protein source, but refined oils became the leading fat source, and milk, chicken, and cooked meals gained prominence. Karnataka's household food basket thus became less dependent on carbohydrate-rich staples and more protein- and fat-intensive in both sectors, although rural–urban differences in food sources persisted and greater diversification did not necessarily imply improved diet quality.

KEYWORDS: Dietary transition; Household Consumption Expenditure Survey; Karnataka; Protein; Rural–urban differences

INTRODUCTION

Economic development, urbanisation, changing livelihoods, market access and household preferences reshape food intake. Across many low- and middle-income countries, cereal-dominated diets are giving way to more diverse food baskets containing milk, edible oils, fruits, vegetables, animal-source foods, and commercially prepared products (1–4). In India, demographic, dietary and lifestyle changes have driven this nutrition transition for several decades (5), but its pace and composition vary by region, income group and rural–urban setting.

The declining dietary share of cereals is consistent with Bennett's Law (6), which links rising incomes to a lower share of starchy staples. Cereals nevertheless remain important within an increasingly diverse diet (7), so nutritional outcomes depend on the foods that replace or supplement staples.

The rural–urban differences are a key dimension of dietary change because urban households face different employment patterns, food environments, time constraints, and market access. Studies of rural–urban migration and urbanisation report higher energy, fat and protein intake among urban residents, and urban diets that include more dairy products, fats and oils, fruits, vegetables, sugar and prepared foods (8–10). The improved transport and retail networks have, however, expanded rural access to packaged and prepared foods (9).

Food expenditure alone does not capture the nutritional consequences of dietary change (11–13). Lower cereal budget shares may coexist with continued dependence on cereals for energy, while greater non-cereal expenditure may reflect nutrient-rich foods, processed foods, or both. Converting household food quantities into nutrient equivalents therefore provides a complementary measure of dietary transition (11, 14). Macronutrient totals also conceal changes in the foods supplying them (15).

The successive National Sample Survey (NSS) rounds and the recent Household Consumption Expenditure Survey (HCES) provide detailed household food-consumption data that can be converted into nutrient estimates,

enabling long-term analysis of household nutrient intake and comparison of rural and urban diets. Karnataka is well suited to this analysis as it combines highly urbanised centres with extensive rural areas that differ in production systems, food cultures, and market integration, and a state-level analysis is needed because national averages can obscure substantial regional variation (11, 16, 17).

Gaps in Existing Literature

Three gaps motivate this study. First, existing studies have examined rural–urban food consumption and nutrient intake for selected earlier NSS rounds, while broader Indian studies have analysed regional dietary change up to 2011–12 and the official HCES 2023–24 report provides recent state- and sector-level nutrient estimates. This study extends that evidence by constructing a harmonised Karnataka series across six survey rounds from 1993–94 to 2023–24. Second, prior studies have focused mainly on aggregate intake, food-group patterns, demand responses, or micronutrients, with limited attention to long-run changes in the individual foods supplying carbohydrate, protein, and fat. Third, the combined evolution of staple-calorie dependence, cereal versus diversified protein, and rural–urban differences in nutrient-source composition have not been examined for Karnataka over the full three-decade period.

Accordingly, the study's contribution is not the production of a single new state-level nutrient estimate, but the integration of six survey rounds into a consistent rural–urban account of how macronutrient quantities, staple-calorie dependence, protein-source composition, and the leading food contributors changed together over three decades.

Objectives

The objectives of this study were to (i) examine long-term changes in daily per-capita household intake of carbohydrate, protein, fat, and energy in rural and urban Karnataka from 1993–94 to 2023–24; (ii) compare changes in staple-calorie dependence and protein-source composition; and (iii) identify shifts in the leading food sources of carbohydrate, protein, and fat.

Hypothesis

We hypothesised that, between 1993–94 and 2023–24, household diets in both rural and urban Karnataka shifted away from carbohydrate-rich staples towards fat and animal-source protein, and that rural–urban differences in macronutrient intake and staple dependence narrowed over the period.

Materials and Methods

Study Design

The study used a repeated cross-sectional design based on successive rounds of household intake data for Karnataka, a southern Indian state with substantial variation in food practices, agricultural production, market access, and urbanisation. Rural and urban households were analysed separately to examine long-term changes in estimated per-capita household macronutrient and energy intake between 1993–94 and 2023–24.

Data Sources and Study Period

The household intake data were drawn from the 50th (1993–94), 55th (1999–2000), 61st (2004–05), 66th (2009–10), and 68th (2011–12) rounds of the National Sample Survey and from HCES 2023–24. Historical item-level food quantities were harmonised across rounds, and Karnataka microdata were analysed for HCES 2023–24. The HCES 2023–24 analytical sample comprised 12,532 households, including 6,728 rural and 5,804 urban households. Nutrient estimates were derived using official NSS conversion coefficients, and the official nutritional-intake report for each round supplied comparison and validation values (18–23).

Data Processing and Nutrient Computation

HCES 2023–24 microdata was processed in Python, with food items standardised across rounds and comparable items grouped into common categories. Household quantities were converted to grams per person per day and matched to official coefficients to estimate per-capita carbohydrate, protein, fat, and energy intake, following NSS terminology and validated against published NSS and NSO aggregates (18–23). The analysis used the household multiplier, household size, survey stratum, and first-stage unit identifiers supplied in the unit-level files.

A common food-item classification was constructed before nutrient conversion. Items with changing labels or codes were mapped to the same analytical category only when their food content and reported unit were comparable; otherwise, they were retained separately or excluded from source-ranking comparisons. The same classification was applied to rural and urban observations.

Estimation of Macronutrient Intake

For each food item, nutrient intake was estimated as follows:

$$N_{ij} = \frac{Q_{ij} \times n_j}{100}$$

Here, nutrient intake for each food item and household is calculated from the edible quantity consumed (g/person/day) and the nutrient content per 100 g. Item-level contributions were summed to obtain daily per-capita carbohydrate, protein, and fat intake (g/person/day).

Estimation of Total Energy Intake

$$E_{ij} = \frac{Q_{ij} \times e_j}{100}$$

Here, the energy supplied by each food item is calculated from its edible quantity (g/person/day) and energy content (kcal per 100 g). Summing across all food items gives total energy intake (kcal/person/day):

$$TE_i = \sum_{j=1}^n E_{ij}$$

Calorie Intake Index

A Calorie Intake Index was constructed to compare observed calorie intake with the conventional norms historically used for India's rural and urban populations: 2,400 kcal per person per day in rural areas and 2,100 kcal per person per day in urban areas (22, 24, 25).

$$CII_{rt} = \frac{\text{Observed calorie intake}_{rt}}{\text{Reference calorie norm}_r} \times 100$$

The index was calculated by sector and survey round; a value of 100 indicates that average calorie intake equals the relevant norm.

Staple-Calorie Share

To assess changes in reliance on staple foods, the share of total energy supplied by cereals and cereal-based foods was calculated for each survey round:

$$\text{Staple calorie share (\%)} = \frac{\text{Energy from staple cereals}}{\text{Total energy intake}} \times 100$$

Protein-Source Composition

Total protein intake was divided into animal-based protein (milk and milk products, eggs, fish, and meat) and plant/other protein (cereals, pulses, and all remaining foods), each reported in grams per person per day and as a percentage of total protein intake.

Protein Diversification

Protein intake was further separated into cereal, pulse, milk, eggs, fish and meat (EFM), and other diversified sources. For this study, diversified protein was operationally defined as protein from milk, EFM, and other non-cereal, non-pulse sources:

Diversified protein = Milk protein + EFM protein + Other diversified protein

The Diversified-to-Cereal Protein Ratio (DPCR) was then calculated as follows:

$$DPCR = \frac{\text{Diversified protein}}{\text{Cereal protein}}$$

Identification of Major Nutrient Sources

For rural and urban Karnataka, the top five food sources of carbohydrate, protein, and fat in 1993–94 and 2023–24 were identified by ranking item-level contributions, reported as absolute amounts and as shares of total nutrient intake. Foods were then classified as those remaining in the top five in both periods, those dropping out, and those entering by 2023–24.

$$\text{Contribution share (\%)} = \frac{\text{Nutrient supplied by the food item}}{\text{Total nutrient intake}}$$

Statistical Analysis

For HCES 2023–24, sector means were estimated using person weights calculated as the household multiplier multiplied by household size. Rural–urban differences in carbohydrate, protein, fat, and energy intake were estimated using separate survey-weighted regressions of each outcome on an urban-sector indicator, with rural households as the reference category. Variance estimation accounted for the survey strata and first-stage units (FSUs) identified in the unit-level data, following the official NSS/HCES sample design. The results are reported as urban-minus-rural differences with design-adjusted standard errors, 95 per cent confidence intervals (CIs), and p-values, with $p < 0.05$ denoting statistical significance. Formal statistical inference is limited to the 2023–24 rural–urban comparisons; changes across survey rounds and in derived indicators are interpreted descriptively.

RESULTS

Long-Term Changes in Macronutrient and Energy Intake

In rural Karnataka, carbohydrate intake decreased from 391.02 g/person/day in 1993–94 to 333.79 g/person/day in 2023–24 (Table 1), while protein increased from 52.62 to 60.68 g/person/day and fat increased sharply, from 24.82 to 65.06 g/person/day. Energy rose more modestly, from 1,997.93 to 2,163.38 kcal/person/day, with some fluctuation across intervening rounds. Urban Karnataka followed a similar pattern: carbohydrate declined from 352.09 to 334.82 g/person/day, protein rose from 49.63 to 63.60 g/person/day, fat more than doubled from 33.21 to 70.96 g/person/day, and energy increased from 1,905.75 to 2,232.28 kcal/person/day.

By 2023–24, carbohydrate intake did not differ significantly between rural and urban Karnataka (difference 1.03 g/person/day; 95% CI –2.82 to 4.87; $p = 0.601$). Urban households, however, had significantly higher estimated intake of protein (difference 2.92 g/person/day; 95% CI 2.12 to 3.72), fat (5.90 g/person/day; 95% CI 4.90 to 6.91), and energy (68.90 kcal/person/day; 95% CI 44.04 to 93.76) than rural households (all $p < 0.001$; Table 2).

Table 1. Daily per-capita macronutrient, energy, and staple-cereal energy intake in rural and urban Karnataka across NSS and HCES rounds.

Round/year	Carbohydrate (g)	Protein (g)	Fat (g)	Energy (kcal)	Staple energy (kcal)	Staple-calorie share (%)
RURAL						
50 th (1993–94)	391.02	52.62	24.82	1997.93	1447.10	72.43
55 th (1999–2000)	363.42	52.64	35.38	1982.64	1307.62	65.95
61 st (2004–05)	337.12	47.45	33.42	1839.05	1223.75	66.54
66 th (2009–10)	350.22	51.62	45.81	2019.64	1147.20	56.80
68 th (2011–12)	370.75	55.83	50.44	2160.26	1114.82	51.61
HCES (2023–24)	333.79	60.68	65.06	2163.38	928.41	42.91
URBAN						
50 th (1993–94)	352.09	49.63	33.21	1905.75	1169.94	61.39
55 th (1999–2000)	353.84	53.16	45.00	2033.01	1152.58	56.69
61 st (2004–05)	337.50	51.07	43.07	1941.92	1107.10	57.01
66 th (2009–10)	353.53	54.86	53.42	2114.34	1050.13	49.67
68 th (2011–12)	367.20	59.04	59.78	2242.97	1002.46	44.69
HCES (2023–24)	334.82	63.60	70.96	2232.28	848.49	38.01

Note: Values are per person per day. Staple-calorie share is staple-cereal energy as a percentage of total energy. Source: Authors' calculations based on NSS and HCES data, using official NSS and NSO nutrient-conversion tables.^{18–23}

Table 2. Rural–urban differences in daily per-capita carbohydrate, protein, fat, and energy intake in Karnataka, HCES 2023–24.

Outcome	Rural mean	Urban mean	Urban – Rural difference	Design-adjusted SE	95% CI	p-value
Carbohydrate (g/person/day)	333.79	334.82	+1.03	1.960	–2.82 to 4.87	0.601
Protein (g/person/day)	60.68	63.60	+2.92	0.409	2.12 to 3.72	<0.001
Fat (g/person/day)	65.06	70.96	+5.90	0.514	4.90 to 6.91	<0.001
Energy (kcal/person/day)	2163.38	2232.28	+68.90	12.684	44.04 to 93.76	<0.001

Note: SE = standard error; CI = confidence interval. Means were estimated using person weights calculated as the household multiplier multiplied by household size. Differences were estimated from separate survey-weighted regressions of each nutrient on an urban-sector indicator, with rural households as the reference category. Variance estimation accounted for the survey strata and first-stage units (FSUs) identified in the unit-level data, following the official NSS/HCES sample design. Source: Authors' calculations based on HCES 2023–24 microdata.

Calorie Intake Index and Staple-Calorie Share

The Calorie Intake Index increased from 83.25 in 1993–94 to 90.14 in 2023–24 in rural Karnataka, remaining below the conventional rural reference of 2,400 kcal/person/day throughout, and from 90.75 to 106.30 in urban Karnataka, exceeding the urban reference of 2,100 kcal/person/day from 2009–10 onwards.

The contribution of staple cereals to energy intake declined markedly (Table 1). Staple energy fell from 1,447.10 to 928.41 kcal/person/day in rural Karnataka and from 1,169.94 to 848.49 kcal/person/day in urban Karnataka, reducing its share of total calories from 72.43 to 42.91 per cent and from 61.39 to 38.01 per cent, respectively.

Protein-Source Composition

The protein sources changed over the study period (Table 3). In rural Karnataka, animal-based protein rose from 5.97 to 15.25 g/person/day, increasing its share of total protein from 11.34 to 25.14 per cent, while the plant/other share declined from 88.66 to 74.86 per cent. In urban Karnataka, animal-based protein rose from 8.56 to 17.78 g/person/day and its share from 17.24 to 27.96 per cent, while the plant/other share decreased from 82.76 to 72.04 per cent. Urban households recorded a higher animal-protein share in every survey round.

Protein Diversification

The protein supply also became more diverse (Table 3). Cereal protein declined from 36.34 to 23.31 g/person/day in rural and from 28.83 to 21.29 g/person/day in urban Karnataka, while diversified protein rose from 10.58 to 31.15 and from 14.55 to 35.89 g/person/day, respectively. Most of this increase came from EFM protein (2.26 to 9.26 g/person/day in rural and 2.92 to 10.53 g/person/day in urban Karnataka) and other diversified protein (4.61 to 15.89 and 6.00 to 18.11 g/person/day), while milk protein rose more modestly (3.71 to 6.00 and 5.64 to 7.25 g/person/day) and pulse protein changed little (5.70 to 6.22 and 6.25 to 6.42 g/person/day). Consequently, the DPCR increased from 0.29 to 1.34 in rural and from 0.50 to 1.69 in urban Karnataka, with the urban ratio remaining higher throughout.

Table 3. Sources, composition, and diversification of daily per-capita protein intake in rural and urban Karnataka across NSS and HCES rounds.

Round/year	Cereal	Pulse	Diversified sources				Total protein	Animal share (%)	DPCR
			Milk	EFM	Others	Total diversified			
RURAL									
50 th (1993–94)	36.34	5.70	3.71	2.26	4.61	10.58	52.62	11.34	0.29
55 th (1999–2000)	33.05	7.17	4.68	2.51	5.23	12.42	52.64	13.66	0.38
61 st (2004–05)	30.57	5.68	4.43	2.23	4.53	11.20	47.45	14.04	0.37
66 th (2009–10)	28.25	5.22	5.10	4.20	8.85	18.15	51.62	18.02	0.64
68 th (2011–12)	27.37	6.81	4.62	5.55	11.49	21.66	55.83	18.21	0.79
HCES (2023–24)	23.31	6.22	6.00	9.26	15.89	31.15	60.68	25.14	1.34
URBAN									
50 th (1993–94)	28.83	6.25	5.64	2.92	6.00	14.55	49.63	17.24	0.50
55 th (1999–2000)	28.39	7.80	6.91	3.73	6.34	16.97	53.16	20.01	0.60
61 st (2004–05)	27.59	6.63	6.55	3.64	6.66	16.84	51.07	19.95	0.61
66 th (2009–10)	26.12	6.20	6.89	5.20	10.45	22.54	54.86	22.03	0.86
68 th (2011–12)	24.80	7.60	6.55	6.46	13.63	26.64	59.04	22.03	1.07
HCES (2023–24)	21.29	6.42	7.25	10.53	18.11	35.89	63.60	27.96	1.69

Note: Values are g/person/day unless stated. EFM = eggs, fish, and meat. Animal-based protein = milk + EFM; the plant/other share (cereal, pulse, and other sources) equals 100 minus the animal share. DPCR = total diversified protein ÷ cereal protein. Source: As for Table 1.

Changes in the Major Food Sources of Carbohydrate, Protein, and Fat

Rice and rice products remained the largest carbohydrate source in both sectors, although their contribution declined (Figure 1), from 136.92 to 131.35 g/person/day in rural and from 160.91 to 122.15 g/person/day in urban Karnataka. Wheat remained among the five leading sources in both sectors. By 2023–24, assisted cooked meals, sugar and sorghum (jowar) had entered the rural top five, while purchased cooked meals, sugar and jowar had become important urban sources.

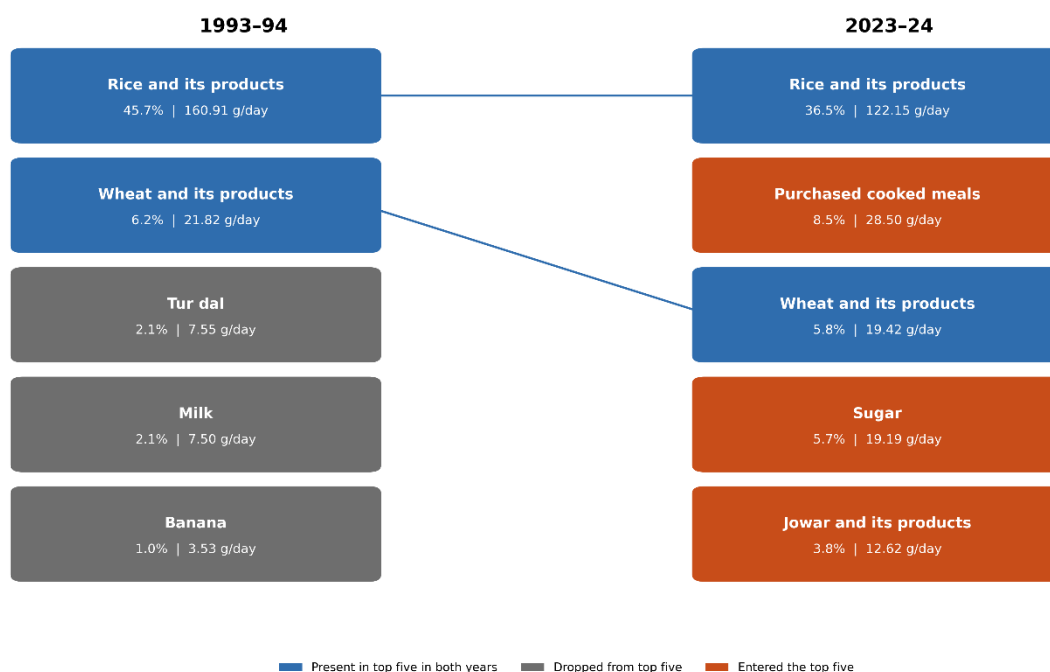
The protein sources became more varied as well (Figure 2). Rice remained the largest rural contributor, although its contribution declined from 13.90 to 13.03 g/person/day; milk and wheat stayed among the leading sources,

and chicken and jowar entered the top five by 2023–24. In urban Karnataka, rice-derived protein fell from 16.33 to 12.11 g/person/day as chicken, milk and purchased cooked meals gained importance.

The sources of fat

changed most dramatically (Figure 3). In rural Karnataka, groundnut oil was the leading source in 1993–94 (7.70 g/person/day), followed by milk (4.40 g/person/day); by 2023–24, refined edible oil dominated at 28.99 g/person/day, milk had risen to 9.73 g/person/day, and groundnut, assisted cooked meals and coconut also ranked among the leading sources. In urban Karnataka, groundnut oil contributed 11.70 g/person/day in 1993–94, whereas refined edible oil supplied 29.80 g/person/day in 2023–24; milk increased from 6.80 to 10.32 g/person/day, and groundnut, purchased cooked meals and coconut also emerged as leading sources.

Top Five Sources of Carbohydrate Intake in Urban Karnataka, 1993–94 and 2023–24



Top Five Sources of Carbohydrate Intake in Rural Karnataka, 1993–94 and 2023–24

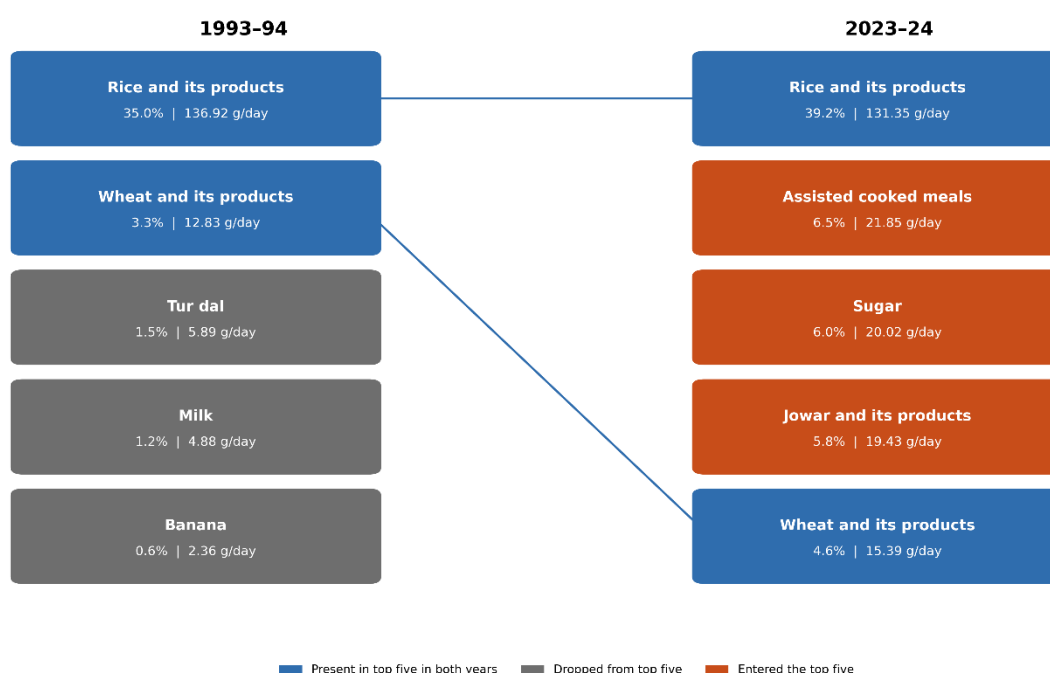


Figure 1. Changes in the five leading food sources of carbohydrate intake in rural (a) and urban (b) Karnataka, 1993–94 and 2023–24.

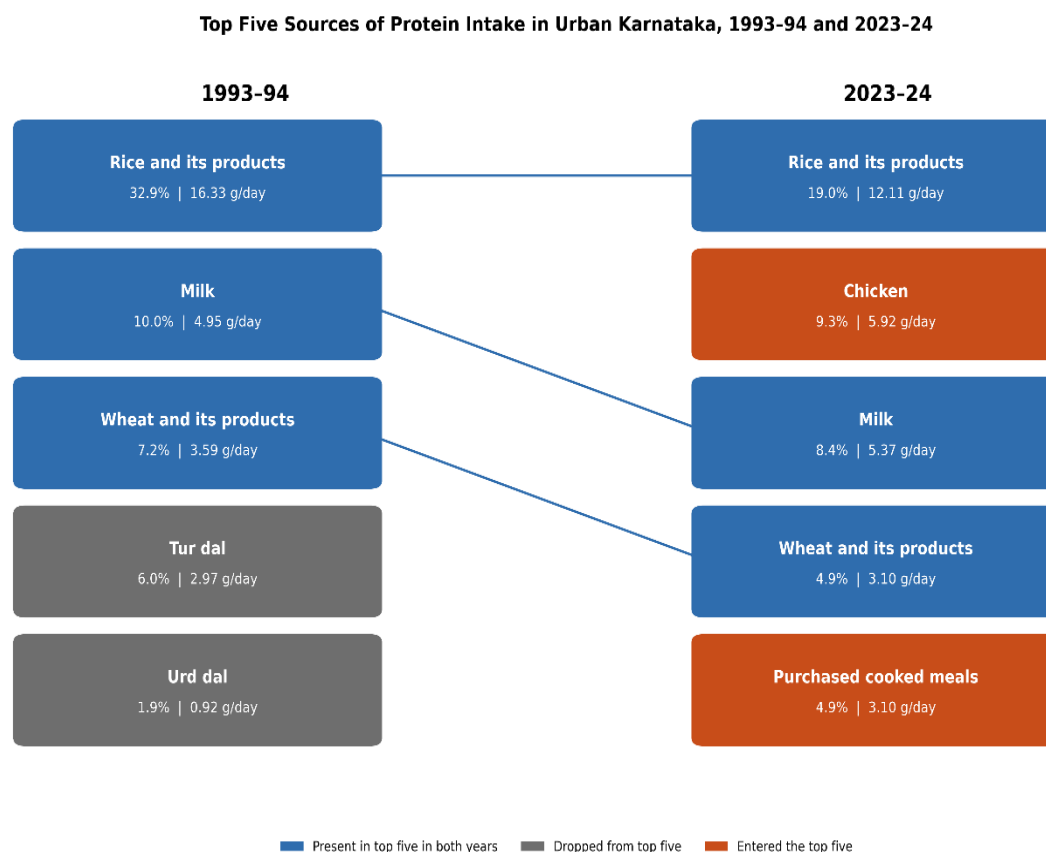
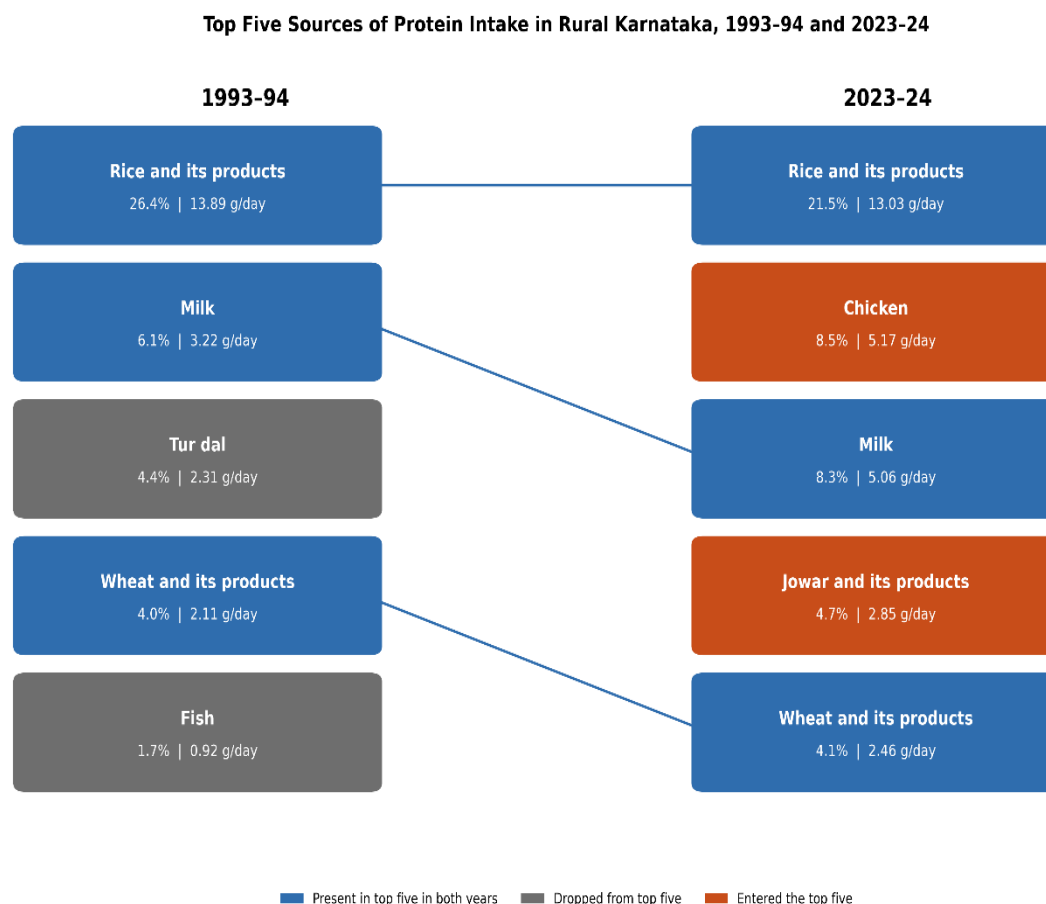


Figure 2. Changes in the five leading food sources of protein intake in rural (a) and urban (b) Karnataka, 1993–94 and 2023–24.

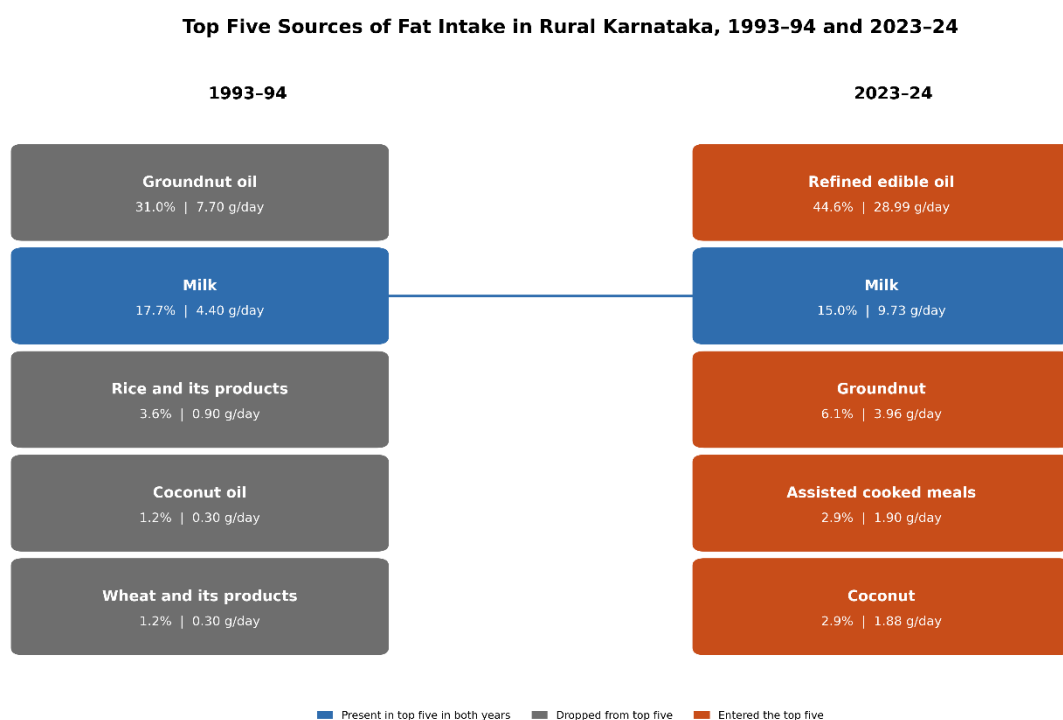
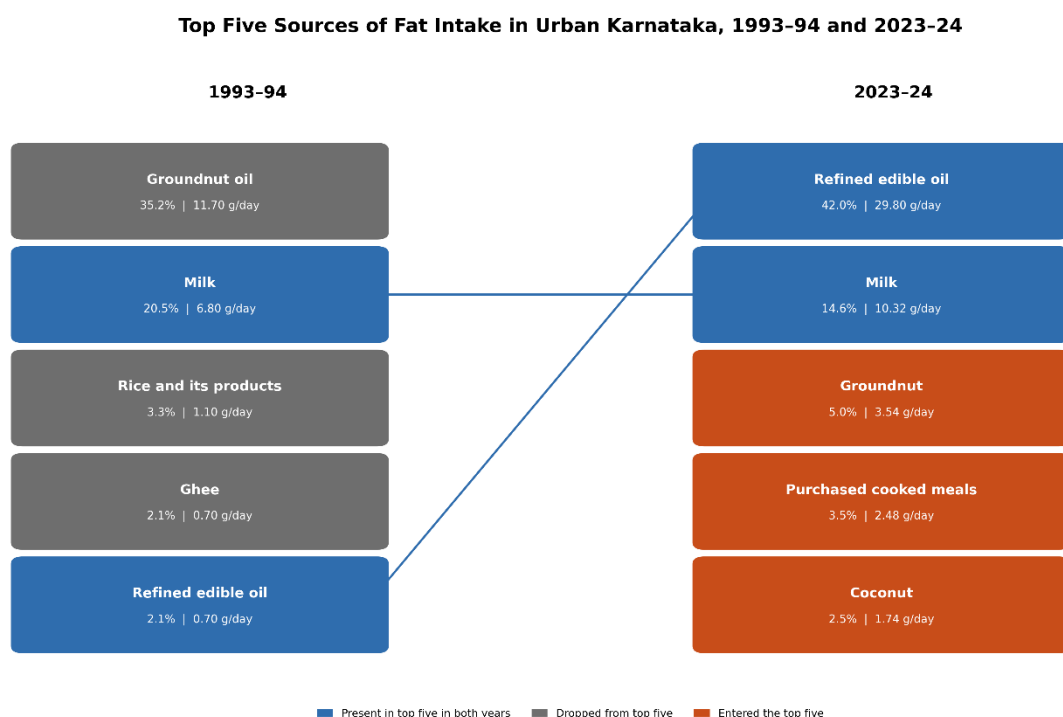


Figure 3. Changes in the five leading food sources of fat intake in rural (a) and urban (b) Karnataka, 1993-94 and 2023-24.

Source for Figures 1-3: Authors' calculations based on NSS and HCES data.

DISCUSSION

Karnataka's nutrition transition reflects a restructuring of the household food basket rather than a uniform increase in food quantity. Declining reliance on carbohydrate-rich staples occurred alongside greater use of edible oils, milk, animal-source foods, and prepared meals. Similar shifts have been reported in India and other rapidly transforming food systems, where rising incomes, urbanisation, market integration, and changing time constraints alter both food preferences and access (5, 10, 17, 27, 28). The coexistence of nutrient-rich foods with

refined oils, sugar, and prepared products also shows why diversification should not automatically be interpreted as improved diet quality (26, 30, 33, 34).

Macronutrient and Energy Transition

The shift from carbohydrate towards fat is consistent with the broader nutrition transition documented in India, in which declining cereal dependence accompanies greater intake of edible oils and other non-staple foods (17, 26). Rising purchasing power can reduce the relative importance of inexpensive staples, while expanded retail networks and food processing make oils, dairy products, animal-source foods, and prepared foods more accessible (10, 27, 28, 32). Because total energy intake changed less markedly than nutrient composition, the Karnataka pattern is better interpreted as macronutrient substitution than as a general expansion of food intake.

The stronger rural shift away from carbohydrate-rich foods may reflect increasing integration of rural households into markets and food environments that were previously more characteristic of urban areas. Improved transport, retail penetration, and access to packaged and prepared foods can reduce dependence on locally produced staples and broaden the range of purchased foods (9, 10, 17, 28). Similar studies associate dietary transition with rising incomes, urbanisation, and changing livelihoods (1, 5, 27), although these mechanisms cannot be tested directly here because the analysis does not include household income, market-access, or employment variables. The non-linear change across survey rounds further indicates that the transition was shaped by period-specific economic and survey conditions rather than by a uniform trajectory (26, 29).

Calorie Intake and the Changing Contribution of Staples

The persistent rural shortfall in the Calorie Intake Index (90.14 in 2023–24, compared with 106.30 in urban Karnataka) cannot, by itself, indicate widespread energy deficiency, because the reference norms derive from late-1970s estimates of requirements (24) and the 2009 Expert group moved away from calorie norms as the basis for poverty measurement (25) equally, the index cannot rule out deficiency in particular groups.

The decline in staple dependence is consistent with Bennett's Law, under which rising incomes reduce the dietary importance of starchy staples as households purchase a wider range of foods.⁶ Indian evidence similarly links greater purchasing power and market access with increased intake of non-staple foods.^{17,28} The nutritional implications depend on what replaces cereals: pulses, milk, fruits, and vegetables can improve nutrient density, whereas refined oils, sugar, and processed foods may increase energy density without comparable gains in diet quality.^{26,30} The findings therefore indicate dietary diversification, but not necessarily nutritional improvement.

Changes in Protein-Source Composition

The movement from cereal protein towards milk, eggs, fish, meat, and other foods is consistent with studies linking urbanisation, income growth, and improved market access to more diverse diets and greater intake of animal-source foods (16, 17, 28, 31). Rampal's analysis of the NSS 61st and 68th rounds provide a close national comparison: cereals remained the principal protein source, rural diets were more cereal-dependent, and urban diets derived relatively more protein from pulses, milk and milk products, and animal-source foods (35). That study associated protein diversification with rising incomes and relative food prices, including substitution towards animal-source protein when pulse prices increased (35). The earlier and persistently higher animal-protein share in urban Karnataka may similarly reflect stronger purchasing power, refrigeration, retail access, and demand for convenience, while the narrowing rural–urban gap suggests that these food-system changes are spreading beyond cities. Pulse protein did not increase comparably, indicating that diversification was driven by dairy, animal-source foods, and other non-cereal items rather than by a broad expansion of traditional plant-protein sources. Because the present analysis did not directly measure prices, income, or access, these mechanisms remain plausible explanations rather than assessed causal pathways.

Protein Diversification and DPCR

The rise in the DPCR reflects two complementary changes: declining dependence on cereal protein and increasing contributions from milk, eggs, fish, meat, and other non-cereal foods. The ratio exceeded 1 earlier in urban Karnataka than in rural Karnataka, indicating that diversified sources became more important than cereals sooner in urban food baskets. The later rural increase suggests diffusion of the same transition beyond cities, consistent with national evidence of declining cereal-protein dependence and increasing contributions from dairy and animal-source foods (23,35). The DPCR therefore captures a structural shift in the composition of household protein intake rather than an increase in protein quantity alone.

The animal-protein share and the DPCR describe related but distinct dimensions of diversification. The animal-protein share captures contributions from milk, eggs, fish, and meat, whereas the DPCR also includes other non-cereal protein sources. The rural diversification therefore advanced without eliminating the urban advantage in the breadth of protein sources. This distinction is important because a higher DPCR indicates reduced cereal dependence, but does not by itself establish protein adequacy, amino-acid quality, affordability, or overall diet quality. Recent Indian evidence likewise cautions that substantial cereal dependence can persist even when total protein intake appears adequate (35).

Changing Major Food Sources of Carbohydrate, Protein, and Fat

The contrasting rice trajectories suggest that dietary transition did not proceed uniformly across sectors. The continued rural reliance on rice alongside declining total carbohydrate intake indicates that reductions occurred mainly in other carbohydrate sources, whereas the urban decline in rice points to broader substitution within the food basket. The falling contribution of rice to protein in both sectors, together with the growing importance of

milk, chicken, and cooked meals, is consistent with the wider Indian shift from cereal-dominated protein towards dairy, animal-source, and other diversified foods (17,28,35). These changes indicate diversification of nutrient sources, although their nutritional implications depend on the quality, processing, and affordability of the foods replacing traditional staples.

The replacement of groundnut oil by refined edible oils is consistent with the wider transformation of Asian food systems, where industrial processing, longer supply chains, modern retail, and relatively inexpensive vegetable oils have altered household fat sources (17, 32). The growing importance of assisted and purchased cooked meals likewise points to changing time constraints, employment patterns, institutional feeding, and greater reliance on food prepared outside the home (8-10). Comparable research warns that such diversification is nutritionally heterogeneous: milk and animal-source foods may increase the supply of high-quality protein and micronutrients, whereas refined oils, sugar, and highly processed foods may increase energy density without improving overall diet quality (3, 29, 33, 34).

Rural–Urban Convergence and Persistent Differences

The convergence in carbohydrate intake and staple dependence suggests that rural and urban food environments are becoming more similar, particularly as rural households gain access to non-staple, packaged, and prepared foods (9,10,17). Comparable studies associate such convergence with market integration, transport improvements, urban influence, and changing livelihoods, although these mechanisms were not measured directly in this study (1,27,28). Persistent urban advantages in protein-source diversity and total protein, fat, and energy intake indicate that convergence remains incomplete and may reflect continuing differences in purchasing power, food access, and demand for convenience (16,31). Thus, Karnataka appears to be experiencing diffusion of urban dietary patterns into rural areas rather than complete rural–urban nutritional convergence.

Directions for Further Research

Further research should examine whether these household-level shifts are reflected in individual intake and nutritional status; which foods account for the rural carbohydrate decline and the “other diversified” protein category; why pulse protein has stagnated; the nutrient quality of assisted and purchased cooked meals; and variation across income groups and districts within Karnataka.

Policy Implications

The findings support monitoring macronutrient balance, food sources, dietary diversity, and the degree of food processing alongside total calorie intake. Policies should promote affordable access to pulses, milk, fruits, vegetables, eggs, fish, and meat while monitoring the growing contribution of refined oils, sugar, and energy-dense prepared foods. The rural findings point to the need to sustain access to diverse protein sources, whereas the urban findings underscore the importance of improving the nutritional quality of purchased cooked meals. Because higher protein and fat intake can arise from foods with markedly different nutritional profiles, these changes should not be interpreted as evidence of improved diet quality without information on nutrient density, processing level, and individual dietary adequacy.

Strengths and Limitations

The study has four principal strengths. First, it provides a three-decade state-level series spanning six NSS and HCES rounds. Second, it analyses rural and urban Karnataka separately, allowing long-term convergence and persistent differences to be examined. Third, it applies the official NSS/HCES sample design and reports design-adjusted inference for the 2023–24 comparison. Fourth, it extends beyond aggregate macronutrient intake to examine staple-energy dependence, protein-source composition, the Diversified-to-Cereal Protein Ratio, and leading food sources.

The study also has limitations. First, the NSS and HCES record food intake at the household level, so, as in the official NSS reports, per-capita nutrient intake is derived from household intake rather than directly observed for individuals and cannot capture intra-household food allocation or differences in requirements by age, sex, or physical activity. Second, changes in food-item classifications, recall periods and survey design across rounds required harmonisation and may affect comparability. Third, the Calorie Intake Index relies on conventional benchmarks and is only a historical comparator. Finally, the rural–urban comparisons are unadjusted, so the differences may partly reflect household size, income, or other characteristics.

CONCLUSION

Between 1993–94 and 2023–24, Karnataka’s household food intake shifted away from cereal-dominated patterns towards lower per-capita carbohydrate intake and higher protein and fat intake. The staple share of energy and cereal protein declined, while animal-based and diversified protein increased; the transition was more advanced in urban Karnataka but was also substantial in rural areas. The hypothesis was therefore partly supported: the shift away from staples occurred in both sectors, and rural–urban carbohydrate intake no longer differed significantly by 2023–24, but urban households retained significantly higher protein, fat, and energy intake. Rice remained a major carbohydrate and protein source, while refined edible oils, milk, chicken, and cooked meals gained prominence. Karnataka’s nutrition transition is therefore best understood through changes in both nutrient quantities and their food sources, although these household-derived intake estimates cannot establish individual dietary adequacy or improved diet quality.

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Conflict of Interest

The authors do not have any conflict of interest.

Data Availability Statement

The raw HCES 2023–24 data are available through the official Government of India survey data portal, subject to the portal's access conditions. Author-generated materials, including the cross-round item concordance, nutrient-coefficient mapping, and analysis code used after decoding, are available from the corresponding author upon reasonable request.

Ethics Statement

This study used secondary, de-identified household survey data and did not involve direct interaction with human participants. Ethical approval was not sought because the analysis relied on publicly accessible, officially released survey data.

Informed Consent Statement

This study involved secondary analysis of de-identified household survey data with no direct participant contact; therefore, individual informed consent was not obtained for this analysis.

Clinical Trial Registration

This research does not involve any clinical trials.

Permission to Reproduce Material from Other Sources

Not applicable.

Author Contributions

Chaitanya Gangadhara: Conceptualisation, methodology, data curation, formal analysis, investigation, visualisation, validation, and writing the original draft.

Jagannath Olekar: Supervision, review and editing, and research guidance.

Lokesha Huchaiiah: Supervision and critical review.

Usha Ravindra: Supervision and critical review.

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Abbreviations

Abbreviation/term	Full form/definition
Assisted cooked meals	: Cooked meals received free of cost by household members from outside the household, such as school mid-day meals, Anganwadi meals, and meals provided by employers or others, as recorded in the HCES
CI	: Confidence interval
DPCR	: Diversified-to-Cereal Protein Ratio
EFM	: Eggs, fish, and meat
HCES	: Household Consumption Expenditure Survey
NSO	: National Statistical Office
NSS	: National Sample Survey
Purchased cooked meals	: Cooked meals bought by household members and consumed from outside the household, such as from hotels, restaurants, canteens, and eateries, as recorded in the HCES
SE	: Standard error

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