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## Comparative appraisal of NRC and ARC feeding standards for tropical climate

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### Abstract

For close to half a century, livestock nutritionists across the globe have leaned on two dominant reference frameworks to calculate what animals should be fed: the NRC system built by the United States' National Research Council and the ARC system assembled by Britain's Agricultural Research Council. Both were shaped almost entirely from feeding trials run on high performing breeds housed under temperate, climate-controlled conditions, yet their tables and equations have travelled far beyond that original setting and now underpin ration decisions across South Asia, Sub Saharan Africa and Latin America. This appraisal sets the two systems next to each other, tracing how each was constructed, what nutritional currency each relies on, and how each holds up once transplanted into hot, humid and resource variable tropical production environments. Particular attention is paid to how indigenous breed physiology, fluctuating forage quality and thermal load reshape the practical meaning of "requirement" in these settings and how regional efforts from Kearn's extrapolated tables to ICAR's breed specific recommendations have tried to narrow the gap. The appraisal closes by arguing for a coordinated, tropically grounded research agenda rather than continued reliance on standards built for a different climate altogether.

**Keywords:** NRC feeding standards, ARC feeding standards, tropical livestock nutrition, nutrient requirements

### Introduction

Ask any nutritionist trained anywhere in the world which reference tables shaped their early ration calculations and two acronyms will almost certainly surface NRC and ARC. The National Research Council's publications, produced through American academic and government collaboration and the Agricultural Research Council's British counterparts, both trace their intellectual roots to a burst of systematic livestock research carried out roughly between the 1940s and the 1980s. That era's experimental work happened almost exclusively on animals kept under regulated, temperate housing and the resulting numbers were folded into what became the default global curriculum for animal nutrition (McDonald *et al.*, 2011) [11]. Decades later, those same figures continue to anchor teaching and extension material well outside the geographic and climatic zones where they were generated. Whether that transplantation is scientifically sound is a question that keeps resurfacing in nutrition circles. Tropical livestock operate under a cluster of conditions thermal, nutritional, and genetic that diverge sharply from the controlled environments in which NRC and ARC figures were derived (Mahgoub and Lu, 1998) [10]. Elevated ambient temperature alone is enough to depress voluntary intake and push maintenance energy costs upward and indigenous breeds carry inherited physiological adaptations that alter how they process and partition nutrients in ways the Western built models were never designed to capture. Layered on top of this is the reality of tropical feed resources themselves: crop residues, native rangeland grasses and by products of agro processing are typically coarse, low in digestibility and swing considerably with season (Sirohi *et al.*, 2015) [17]. Even where locally generated research exists, it has yet to coalesce into a single, institutionally endorsed tropical standard. Field level practice in most

developing regions still defaults to NRC or ARC figures, propped up by informal, unvalidated adjustments made by individual practitioners as circumstances demand (Kearl, 1982) [9]. What follows is an attempt to lay the two parent systems side by side examining how each was built, what conceptual ground each occupies and where the translation to tropical practice becomes most consequential.

### How NRC and ARC Were Built and Methodological Foundations

The NRC framework has been revised repeatedly and independently for each livestock category such as dairy cattle (NRC, 2001), beef cattle (NRC, 2000), sheep and goats jointly (NRC, 2007) and poultry (NRC, 1994), to name the major titles. Each edition draws together controlled feeding trials, factorial breakdowns of requirement and increasingly, meta-analytic synthesis of accumulated data to arrive at figures for energy, protein, minerals and vitamins across a spread of production scenarios. Of particular note is how far the dairy cattle edition has moved toward mechanistic, rather than purely empirical, modelling and its equations now attempt to trace rumen fermentation kinetics and amino acid flow at a near metabolic level of detail (NRC, 2001). ARC took a different publishing path, consolidating its

recommendations into single comprehensive monographs namely one for ruminants (ARC, 1980) and a separate volume for pigs (ARC, 1981) rather than the NRC's species by species series. Its architecture was strictly factorial, decomposing total nutrient need into discrete additive components for maintenance, growth, pregnancy and lactation. ARC is also where the concept of metabolizable energy (ME) and later metabolizable protein (MP), became firmly entrenched as the preferred nutritional currency, a convention subsequently carried forward into related British and European frameworks such as AFRC (1993). Its treatment of protein was, by most accounts, ahead of its time: ARC was among the earliest systems to formally separate rumen degradable from rumen undegradable protein fractions, a distinction that predated much of the terminology used in modern protein systems (Orskov and McDonald, 1979) [16].

What both systems share, structurally, is a dependence on data drawn almost entirely from high yielding European and North American genotypes reared under near ideal environmental management. That is not a flaw in method so much as a boundary on scope. One that only becomes a practical concern once the tables are lifted out of their originating context and applied elsewhere without adjustment.

**Table 1:** Structural Comparison of NRC and ARC Feeding Systems

| Feature                  | NRC (USA)                                         | ARC (UK)                                                      |
|--------------------------|---------------------------------------------------|---------------------------------------------------------------|
| Country of origin        | United States                                     | United Kingdom                                                |
| Dominant energy currency | Net Energy (NE) / TDN                             | Metabolizable Energy (ME)                                     |
| Protein framework        | Metabolizable Protein (MP); RDP/RUP model         | Metabolizable Protein (MP); degradability based               |
| Overall approach         | Blend of empirical data and mechanistic modelling | Factorial (maintenance plus each production function)         |
| Species covered          | Cattle, sheep, swine, poultry, horses, goats      | Cattle, sheep, pigs (monograph format)                        |
| Breed data base          | High producing temperate breeds                   | High producing temperate breeds                               |
| Climate assumed          | Temperate, thermoneutral                          | Temperate, thermoneutral                                      |
| Update cycle             | Ongoing, species specific revisions               | Largely static post 1980; succeeded functionally by AFRC 1993 |

Compiled from NRC (2001), ARC (1980) and AFRC (1993).

"A model calibrated on a Holstein cow in a climate controlled barn is answering a different physiological question than the one posed by a Sahiwal grazing at 40 °C."

### The Tropical Production Context

Transplanting either framework into a tropical setting means reckoning with a cluster of physiological and environmental realities that simply were not part of the original experimental design.

#### Thermal load and its metabolic cost

Animals housed in hot, humid environments undergo a cascade of thermoregulatory adjustments. Intake typically falls, respiratory rate climbs and blood flow shifts toward peripheral tissue and away from the visceral organs that drive digestion, all of which changes both digestive efficiency and how absorbed nutrients get partitioned (Bernabucci *et al.*, 2010) [4]. Thermoregulation itself is metabolically expensive, meaning that maintenance energy costs under genuine heat load can run noticeably above the figures either NRC or ARC assume. Correction factors for this have started appearing in the more recent literature (Dikmen and Hansen, 2009) [6], but neither parent system built such adjustments into its original requirement tables.

#### Breed physiology and metabolic efficiency

Cattle, sheep and goat breeds native to tropical regions such as Sahiwal, Red Sindhi, Murrah buffalo, Barbari goats, Nellore cattle carry metabolic and physiological traits shaped by generations of selection under heat and scarcity, traits that

set them apart from the Holstein Friesian, Angus, or Suffolk animals that populated most NRC and ARC feeding trials (Devendra, 2001) [5]. These indigenous genotypes generally convert energy and protein less efficiently into production output, yet they tend to hold up far better under nutritional scarcity, parasite pressure and thermal stress than their temperate counterparts. Applying maintenance allowances lifted directly from NRC or ARC tables to such animals tends to produce a mismatch in either direction sometimes over supplying nutrients relative to genetic potential and at other times under supplying once the true environmental burden is factored in.

#### Feed base and digestibility variability

The feed resources that dominate tropical rations like mature fibrous forage, cereal straws and stovers carry nutritional value that shifts considerably with season, plant maturity and how the material was handled after harvest. The digestibility coefficients baked into NRC and ARC calculations were generated almost entirely from temperate legumes, grasses and concentrates. It carries those same coefficients over to tropical roughage typically overstates the energy and protein an animal can actually extract producing rations that appear balanced on paper while falling short in the animal (Kearl, 1982; Sirohi *et al.*, 2015) [9, 17].

### Mineral supply and soil interactions

Many tropical soils run low in selenium, copper, zinc and cobalt. The fraction of these minerals that forages actually make bioavailable can diverge substantially from the assumptions embedded in NRC and ARC mineral tables.

High soil iron content, common across several tropical regions, further antagonizes copper absorption, a factor that has repeatedly rendered NRC based supplementation schedules insufficient in Indian and African field trials (Garg *et al.*, 2013) [7].

**Table 2:** Assumption versus Reality Snapshot for Tropical Application

| Parameter               | NRC / ARC Assumption                        | Typical Tropical Condition                      |
|-------------------------|---------------------------------------------|-------------------------------------------------|
| Ambient temperature     | Thermoneutral zone, roughly 15–20°C         | Frequently 30–45°C, often with high humidity    |
| Maintenance energy      | Derived from temperate breed data           | Elevated by heat load and disease pressure      |
| Forage digestibility    | Based on temperate legumes and grasses      | Lower in mature tropical straws and stovers     |
| Voluntary intake        | Ad libitum, under optimal conditions        | Depressed by heat; seasonally interrupted       |
| Breed efficiency        | High yielding crossbred or exotic genotypes | Moderate at best; indigenous breeds predominate |
| Mineral bioavailability | Modelled on temperate soil feed systems     | Often reduced by regional soil antagonists      |
| Water requirement       | Standard fixed allowance                    | Substantially higher under thermal load         |

Compiled from Bernabucci *et al.* (2010) [4], Devendra (2001) [5], Sirohi *et al.* (2015) [17] and Garg *et al.* (2013) [7].

### Setting the Two Systems Against Each Other

From a working nutritionist's standpoint, NRC tends to win out on sheer accessibility. Its tabular format, organized by production class and presented with digestible summaries, has made it the go to reference for feed manufacturers and extension nutritionists throughout much of the developing world. The dairy cattle model in particular has been built into ration balancing software used widely across the industry though it is worth remembering that the biological equations underneath that software remain calibrated to Holstein performance data. ARC, by comparison, has found its firmer footing in university and research settings, where its more rigorous theoretical treatment of protein nutrition particularly the RDP/RUP degradability distinction continues to be valued (Orskov and McDonald, 1979) [16]. The two also part ways on energy currency. NRC's dairy model expresses requirements in net energy terms (NEL, NEM, NEG), whereas NRC's beef cattle volume and the ARC system as a whole lean toward metabolizable energy. That divergence complicates cross referencing for anyone working across species or in the mixed, transitional production systems typical of tropical smallholdings. Where local feed composition tables are assembled from domestic assay data, the choice between these two energy currencies alone can shift a calculated ration's apparent adequacy by something in the order of 10–20% (Mahgoub and Lu, 1998) [10]. One area where the two systems converge and where that convergence works against tropical relevance is genotype by environment interaction. Neither framework built in a mechanism to adjust requirement figures for heat tolerance, coat character, skin pigmentation, or tick resistance, all of which meaningfully shape the real metabolic burden carried by a tropical animal. Researchers in India, Brazil and several African countries have begun filling this gap with breed specific requirement studies of their own, though this body of work remains scattered across individual publications rather than folded into any single, universally recognized standard (Devendra, 2001; Sirohi *et al.*, 2015) [5, 17].

### Regional Efforts Toward Tropical Calibration

Among the earliest and most widely cited attempts to bridge NRC and ARC toward tropical conditions came from Kears (1982) [9] at Utah State University, who assembled nutrient requirement tables aimed specifically at ruminants in developing countries. Building outward from existing ARC and NRC figures, Kears scaled energy and protein

requirements downward to better reflect the smaller body size, lower genetic ceiling, and different feed base typical of tropical livestock. His tables went on to see wide use across South Asia and Sub Saharan Africa and continue to circulate in extension settings today though it is worth noting that the underlying method was one of extrapolation from temperate data rather than direct experimentation under tropical conditions and it does not formally incorporate heat stress, seasonal feed variation, or parasite load.

India's own contribution comes through the Indian Council of Agricultural Research (ICAR), whose published nutrient requirement recommendations for Indian livestock represent a more domestically anchored effort. These figures account for the production capacity, body weight, and performance profile of major Indian breeds such as Murrah buffalo, Sahiwal cattle and Beetal goats among them (ICAR, 2013). Comparable national initiatives have taken shape elsewhere too. Brazil's CNCPS adaptation and several East African programs have emerged from locally funded research though none of these regional efforts has yet achieved the breadth of uptake, or the regular revision cycle, that characterizes the NRC series.

### Conclusion

NRC and ARC remain, without question, landmark achievements in the science of animal nutrition and the methodological discipline both brought to requirement estimation is not in dispute. What is worth reconsidering is the assumption that these frameworks can be carried into tropical livestock systems without deliberate, locally informed recalibration. Doing so risks miscalculated rations that quietly erode animal performance, cut into smallholder farmers' margins and at a policy level get built into feeding recommendations resting on a nutritional baseline that was never designed for the climate in question. At its root, this is not simply a technical shortfall; it reflects how unevenly the global evidence base in livestock science has grown, with high input temperate systems generating a volume and quality of data that tropical settings have yet to match. The path forward points toward treating independently validated, tropically grounded feeding standards as a genuine research priority built on long term feeding trials conducted under real tropical conditions, breed specific physiological datasets, regularly updated local feed composition tables and formal heat stress correction models. Coordinated research networks spanning tropical countries, potentially convened through organizations such as FAO or the International Livestock Research Institute (ILRI), could supply the institutional backbone this agenda needs. Until that infrastructure exists,

the more defensible posture for nutritionists working in tropical environments is to treat NRC and ARC figures as a starting reference rather than a final prescription, a framework to be locally calibrated, not applied precisely.

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