Journal of Ethnopharmacology 152 (2014) 292–301

Contents lists available at ScienceDirect

Journal of Ethnopharmacology

journal homepage: www.elsevier.com/locate/jep

Research Paper

Chemical variability along the value chains of turmeric (*Curcuma longa*): A comparison of nuclear magnetic resonance spectroscopy and high performance thin layer chromatography

Anthony Booker [a], Debora Frommenwiler [b], Deborah Johnston [c], Chinenye Umealajekwu [a], Eike Reich [b], Michael Heinrich [a,d,*]

[a] Centre for Pharmacognosy and Phytotherapy, UCL School of Pharmacy, University of London, UK
[b] CAMAG AG, 4132 Muttenz, Switzerland
[c] School of Oriental and African Studies, University of London, Thornhaugh Street, Russell Square, London, UK
[d] Department of Pharmaceutics and Industrial Pharmacy, Faculty of Pharmacy, King Abdulaziz University, Jeddah, Saudi Arabia

ARTICLE INFO

Article history:
Received 12 June 2013
Received in revised form
17 November 2013
Accepted 20 December 2013
Available online 10 January 2014

Keywords:
Turmeric
Value chains
NMR
HPTLC
Herbal medicinal product
Traditional Asian medicine

ABSTRACT

Ethnopharmacological relevance: Herbal medicine value chains have generally been overlooked compared with food commodities. Not surprisingly, revenue generation tends to be weighted towards the end of the chain and consequently the farmers and producers are the lowest paid beneficiaries. Value chains have an impact both on the livelihood of producers and on the composition and quality of products commonly sold locally and globally and consequently on the consumers. In order to understand the impact of value chains on the composition of products, we studied the production conditions for turmeric (*Curcuma longa*) and the metabolomic composition of products derived from it. We aimed at integrating these two components in order to gain a better understanding of the effect of different value chains on the livelihoods of some producers.

Materials and methods: This interdisciplinary project uses a mixed methods approach. Case studies were undertaken on two separate sites in India. Data was initially gathered on herbal medicine value chains by means of semi-structured interviews and non-participant observations. Samples were collected from locations in India, Europe and the USA and analysed using ^{1}H NMR spectroscopy coupled with multivariate analysis software and with high performance thin layer chromatography (HPTLC).

Results: We investigate medicinal plant value chains and interpret the impact different value chains have on some aspects of the livelihoods of producers in India and, for the first time, analytically assess the chemical variability and quality implications that different value chains may have on the products available to end users in Europe. There are benefits to farmers that belonged to an integrated chain and the resulting products were subject to a higher standard of processing and storage.

By using analytical methods, including HPTLC and ^{1}H NMR spectroscopy, it has been possible to correlate some variations in product composition for selected producers and identify strengths and weaknesses of some types of value chains. The two analytical techniques provide different and complementary data and together they can be used to effectively differentiate between a wide variety of crude drug powders and herbal medicinal products.

Conclusions: This project demonstrates that there is a need to study the links between producers and consumers of commodities produced in so-called 'provider countries' and that metabolomics offer a novel way of assessing the chemical variability along a value chain. This also has implications for understanding the impact this has on the livelihood of those along the value chain.

Abbreviations: AE, aqueous extract; C, cosmetic; DMSO, dimethylsulphoxide; Drh, dried rhizome; EE, ethanolic extract; F, food; FRh, fresh rhizome; GAP, good agricultural practice; HMP, herbal medicinal product; HPMC, hydroxypropyl methylcellulose; HPTLC, high performance thin layer chromatography; LEDC, less economically developed country; LCIRAH, Leverhulme Centre for Integrative Research on Agriculture and Health; M, medicinal; MEDC, more economically developed countries; MHRA, Medicines and Healthcare Products Regulatory Agency; NMR, nuclear magnetic resonance; PCA, principal component analysis; PRC, Peoples Republic of China; PW, Powdered drug; Rf, retention factor; SCF, super critical fluid extract; TCM, traditional Chinese medicine; THMPD, traditional herbal medicinal products directive; VIVC, vertically integrated value chain; WHO, World Health Organisation; WRT, white light

* Corresponding author at: Centre for Pharmacognosy and Phytotherapy, UCL School of Pharmacy, University of London, London, UK.
E-mail address: m.heinrich@ucl.ac.uk (M. Heinrich).

0378-8741
http://dx.doi.org/10.1016/j.jep.2013.12.042

1. Introduction

Ethnopharmacological research has generally focused on herbal starting materials and their composition and effects, or on the final products available to the consumer. There has been a limited focus on the interconnectivities linking producers and consumers (Booker et al., 2012).

On the other hand, global value chain analysis has been commonly applied to food sectors, including tea, coffee and cocoa (Kaplinsky, 2004; Gibbon and Ponte, 2005; Fullbright, 2008) but little work has been undertaken in this area regarding *medicinal plants*. Agricultural production is generally in developing countries, while the consumption is both in developing and developed countries. Clearly such a usage impacts on public health, potentially not only in a beneficial but also detrimental way and it has a direct relevance in the context of ethnopharmacology.

It is an important area for research since the production of high value products is an emerging but poorly understood economic activity within many developing countries, and particularly within India and China, both with a long history of trading in such commodities. According to the World Health Organisation (WHO), world trade in herbal medicine was estimated at $83 Billion in 2008 (Robinson and Zhang, 2012).

Much of the trade in medicinal plants has been based within national market systems. While global trade in high value products like spices and medicines has a long history, e.g. along the spice route (Freedman, 2003), over the last 30 years international trade has flourished and a main thoroughfare of this trade exists between Asia and Europe, the US and Australia.

While ethnopharmacology has historically focused on the 'traditional' uses in far away regions, it is now more and more accepted that the complex interrelationship between producers and consumers needs to be studied from a trans-disciplinary viewpoint (Heinrich et al., 2011).

From a global perspective Europe has been leading the way in supplying high quality herbal products, first with diverse national initiatives and also with the development of quality standards, for example, in the European Pharmacopoeia and, more recently, with the introduction of the EU-wide Traditional Herbal Medicinal Products Directive (THMPD, 2004/24/EC) (European Parliament, C, 2004) which requires well defined minimal standards of quality and safety to be assured before a product can be released onto the market. Therefore, compared with food crops, medicinal plants may be more attractive economically (Alam and Belt, 2009; Sharmin, 2004). However, the European quality requirements for medicinal plants, plant extracts and herbal medicinal products set a much higher entry bar than for foods requiring more sophisticated inputs along the value chain.

The traceability of raw materials used in herbal medicines has always been problematic. In Asia, it is common practice for plants to be collected from the wild or cultivated on small farms and then either stored, for sometimes long periods, sold in the local market, or auctioned at one of the designated auction sites (Kala et al., 2006; van de Kop et al., 2006; Alam and Belt, 2009). Middlemen are usually involved in the supply of plant material to herbal manufacturers and any information regarding the origin and primary processing is mainly lost. An alternative to this approach has been the implementation of vertically integrated value chains (VIVCs) (Fig. 1), where contracts are made between (in our case study) the farmer in Asia and the retailer in Europe.

A VIVC can be defined as when 'a lead organisation' is responsible for two or more intertwined steps of the manufacturing or value chain process (Strategy-Train, 2009). This has advantages for the farmer in that a premium is paid for the crop, and the order size and type of crop grown can be well defined in advance, allowing for an effective planting and cultivation strategy to be developed. For the buyer, the advantages include that the crop has better traceability, a price has been agreed in advance and so market fluctuations are not an issue, and knowledge that good cultivation practice has been employed. India was chosen as a research site as it is a fast developing country with a long tradition of medicinal plant use. It has an established herbal medicine manufacturing base and a thriving export market (Polshettiwar, 2006).

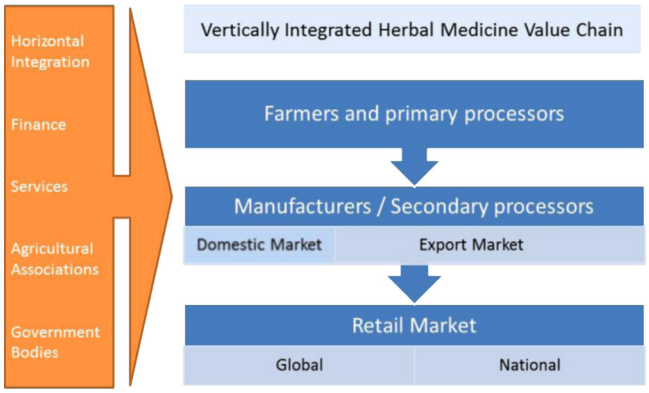

Fig. 1. The generic herbal medicine value chain.

In order to study these inter-relationships, metabolomics offers some novel and bioscientifically robust opportunities. It provides what has been called a 'holistic view' of the metabolites of a set of organisms (Kim et al., 2011) and has been used in a wide range of research fields like plant biotechnology, ethnopharmacology, ecological toxicology and plant physiology (e.g. Verpoorte et al., 2005; Kim et al., 2011; Liu et al., 2011; Michl et al., 2011), and is ideally suited for comparing large number of samples as one would encounter them, for example, along a value chain. At the same time it is a method which as such is not validated and needs to be compared to a standard method like high performance thin layer chromatography (HPTLC), widely used in the authentication and quality control of herbal substances (Reich and Schibli, 2007).

Following an online survey, turmeric (*Curcuma longa* L. Zingiberaceae) was chosen as a suitable case study. Turmeric's use as both food and a medicine presents an opportunity to show how a value chain may be different for a food and a drug and how investing in quality can lead to genuine value addition. There are concerns over the quality of material available commercially. It is acknowledged that the chemical composition is variable and misidentification of species and adulteration are frequently reported problems (Govindarajan, 1980; Dixit et al., 2009). There are several species that may be confused with *Curcuma longa*.

Curcuma aromatica Salisb. (wild turmeric) has been known to be used as an additive in order to improve the colour of cultivated *Curcuma longa*, which in turn raises its auction value, but clearly is an adulteration. In an integrated chain there is less opportunity (or necessity) for adulteration to take place as a price for the crop has already been agreed. An analytical assessment should be able to determine which products have been adulterated. *Curcuma aromatica* does not contain bis-demethoxycurcumin found in *Curcuma longa*.

Curcuma zanthorrhiza Roxb. (Javanese turmeric) is native to Indonesia and is commonly found in HMPs in Europe. It is listed in the British Pharmacopoeia. This species also lacks bis-demethoxycurcumin and is chemically similar *to Curcuma aromatica. Curcuma kwangsiensis* S.G. Lee and C.F. Liang is a Chinese species and favoured for use in traditional Chinese medicine (TCM) products.

This has led to the key research questions of this paper:

- How can the variation of the product composition be determined analytically? And how does this inform the debate about value chains of herbal medicines?