Tissue-specific element profiles in edible seeds

Blaž Režonja[1], Ela Vavpetič[1], Neža Kokalj[1], Aleš Kladnik[1], Primož Vavpetič[2], Mitja Kelemen[2], Paula Pongrac[1,2]

[1] Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, 1000 Ljubljana, Slovenia
[2] Jožef Stefan Institute, Jamova 39, 1000 Ljubljana, Slovenia
paula.pongrac@bf.uni-lj.si; paula.pongrac@ijs.si

UNIVERSITY OF LJUBLJANA Biotechnical Faculty

Jožef Stefan Institute
F2 / Department of Low and Medium Energy Physics

INTRODUCTION

Optimising nutritional yield of existing farmland to feed the increasing global population can be achieved through biofortification [1]. Staple foodstuff, mainly seeds, differ in their element profiles and their distribution can importantly influence the success of biofortification, food processing and diets worldwide. Elemental profiles of tissues in seeds of six nutritionally important dicots (Figure 1) were captured using micro-PIXE. A five-step workflow (Figure 2) was followed: after manual sectioning, microscopy discerned tissues in seeds (Figure 3), distribution analysis depicted tissue-specific allocations of essential elements (Figure 4 disclosing results for Ca, Fe and Zn), image analysis provided their tissue-specific concentrations (Figure 5), and, ultimately, led to the estimation of nutritional potential of each seed (Table 1).

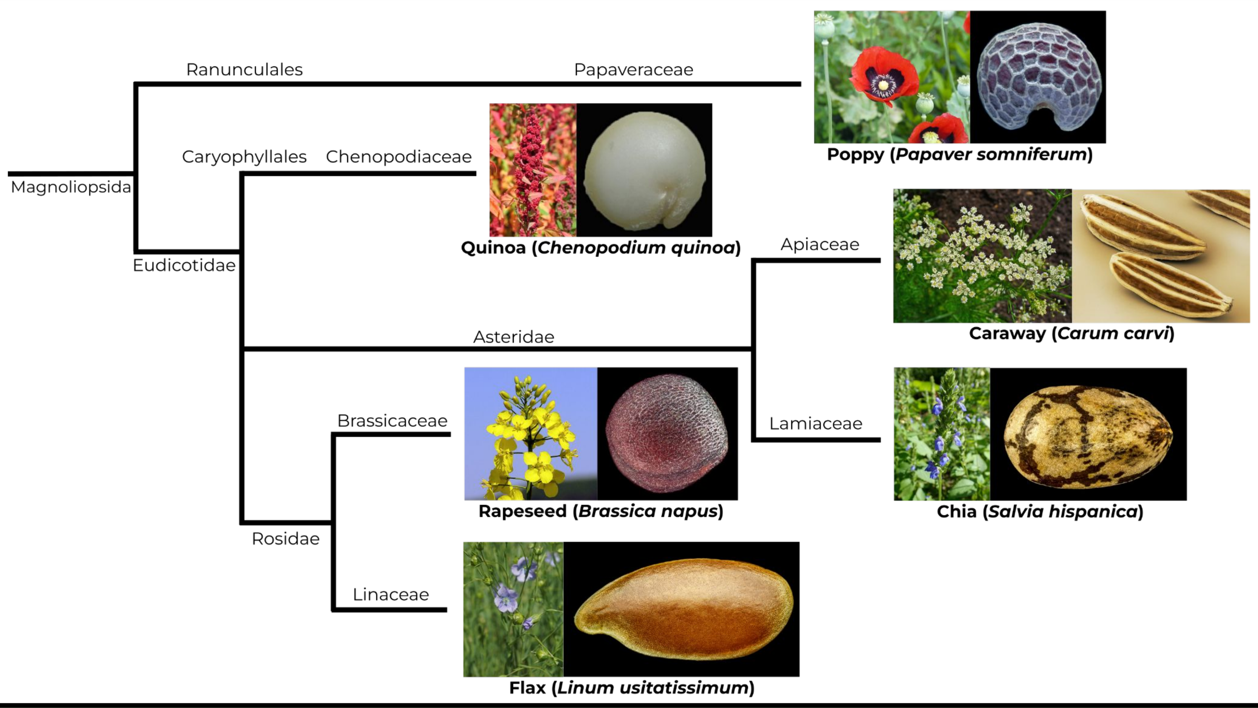

Figure 1: Taxonomic relationships of selected dicot seeds.

RESULTS

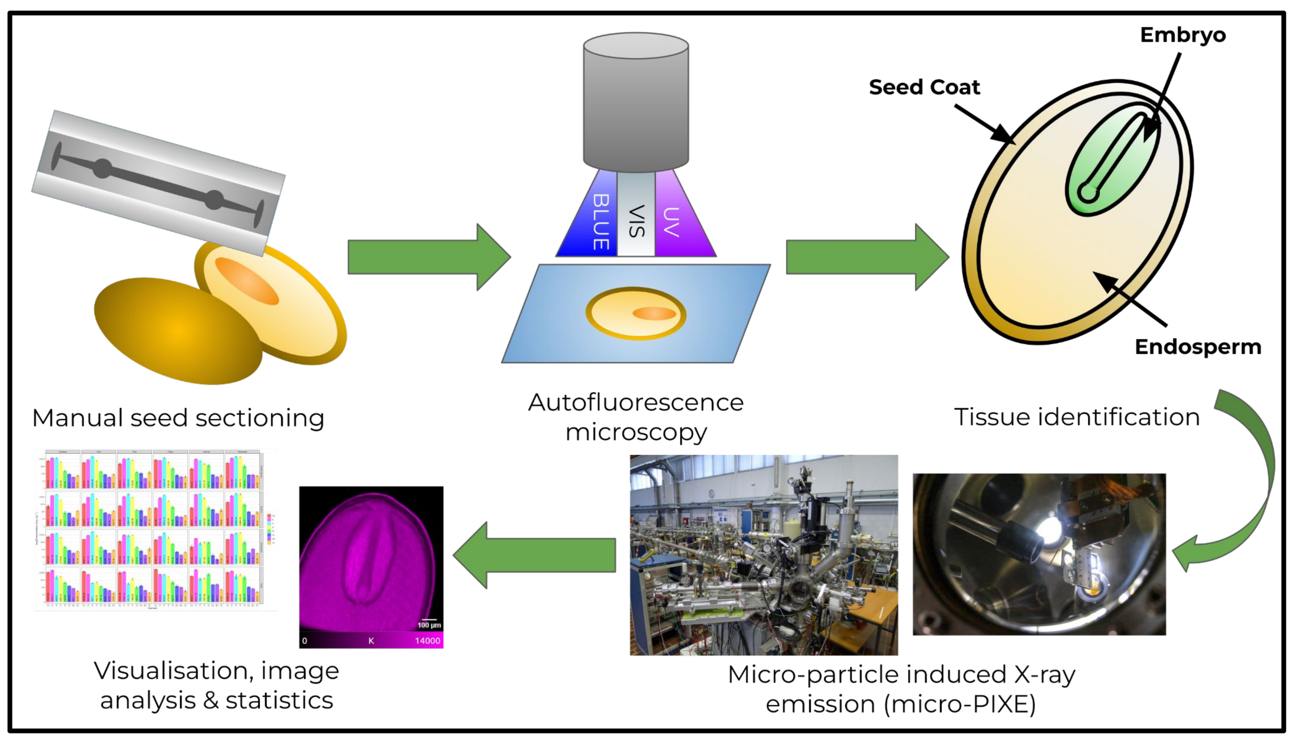

Figure 2: Workflow with key methods.

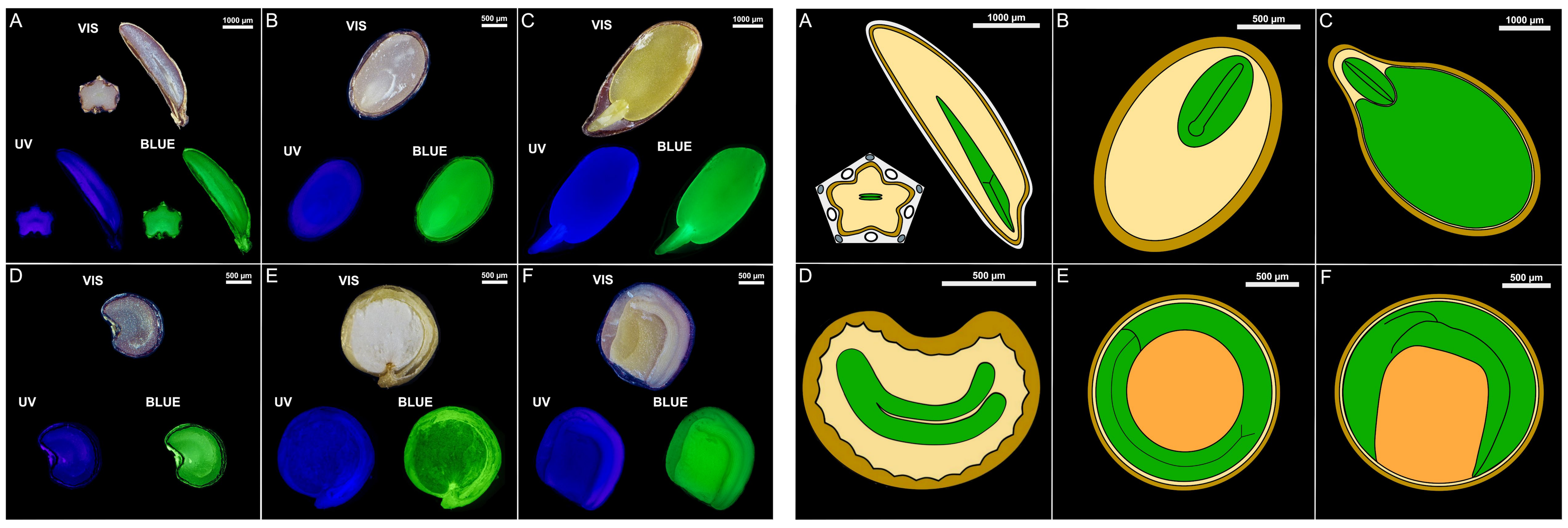

Figure 3: Autofluorescence microscopy of seed cross-sections under white (VIS), ultraviolet (UV) and blue (BLUE) excitation light (left) and microscopy-derived seed cross-section diagrams with colour-coded tissues distinguished: seed coat (brown), endosperm (beige), endosperm (green), perisperm (orange) and auxiliary structures (gray) (right). The displayed seeds are caraway (A), chia (B), flax (C), poppy (D), quinoa (E) and rapeseed (F).

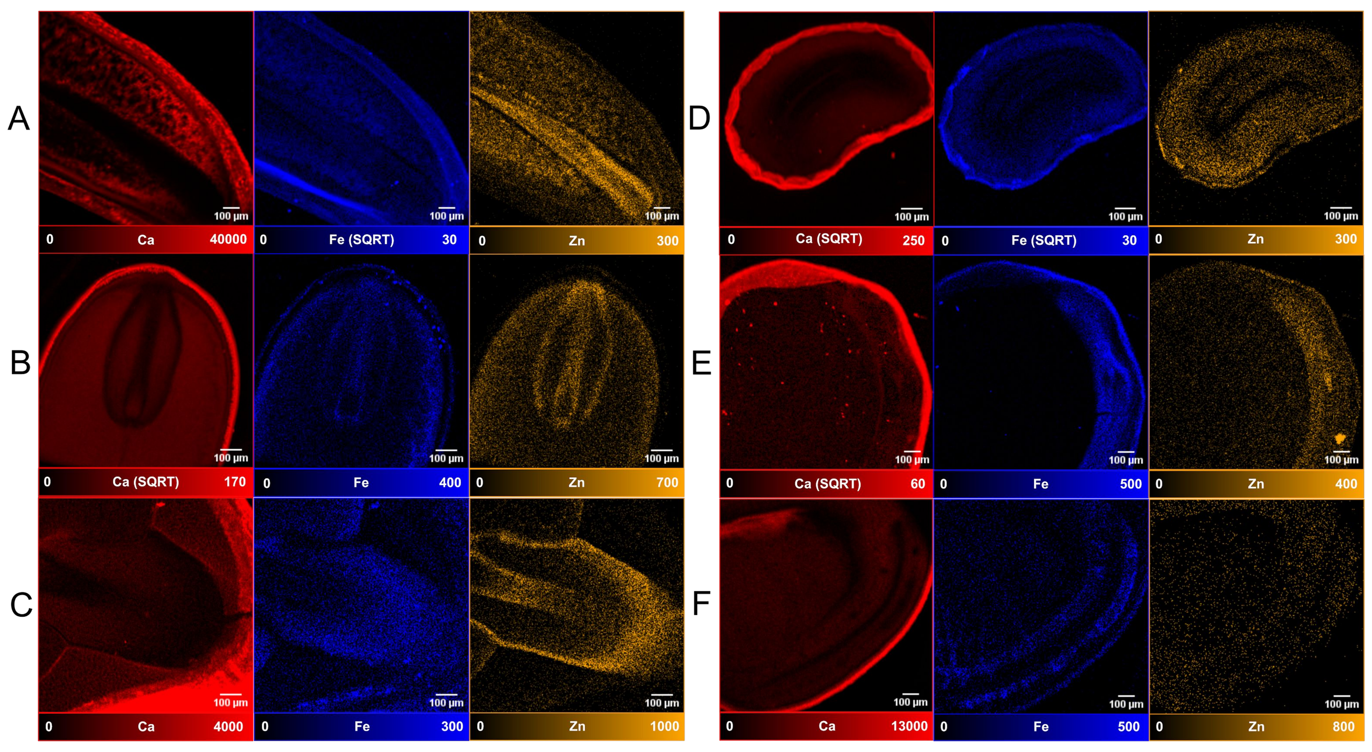

Figure 4: Micro-PIXE localisation maps of Ca, Fe and Zn. Values on colour scales are in mg kg^{-1} dry matter. (SQRT) marks scales of square-rooted concentration values. The displayed seeds are caraway (A), chia (B), flax (C), poppy (D), quinoa (E) and rapeseed (F).

Table 1: Calculated minimum daily intake for adult males and females with all essential elements assumed to be fully bioavailable.

Element	Species	Concentration [mg kg^{-1}]	Male RDI [mg]	Female RDI [mg]	Male Daily Intake [g]	Female Daily Intake [g]
Ca	Caraway	5730	1050		183	
	Chia	3393			309	
	Flax	2326			451	
	Poppy	7818			134	
	Quinoa	518			2025	
	Rapeseed	3096			339	
Fe	Caraway	92	10	17.5	109	190
	Chia	82			123	215
	Flax	118			85	149
	Poppy	69			144	252
	Quinoa	75			133	232
	Rapeseed	74			134	235
Zn	Caraway	57	9.5	7	166	123
	Chia	84			114	84
	Flax	165			58	43
	Poppy	41			234	173
	Quinoa	60			157	116
	Rapeseed	55			173	128

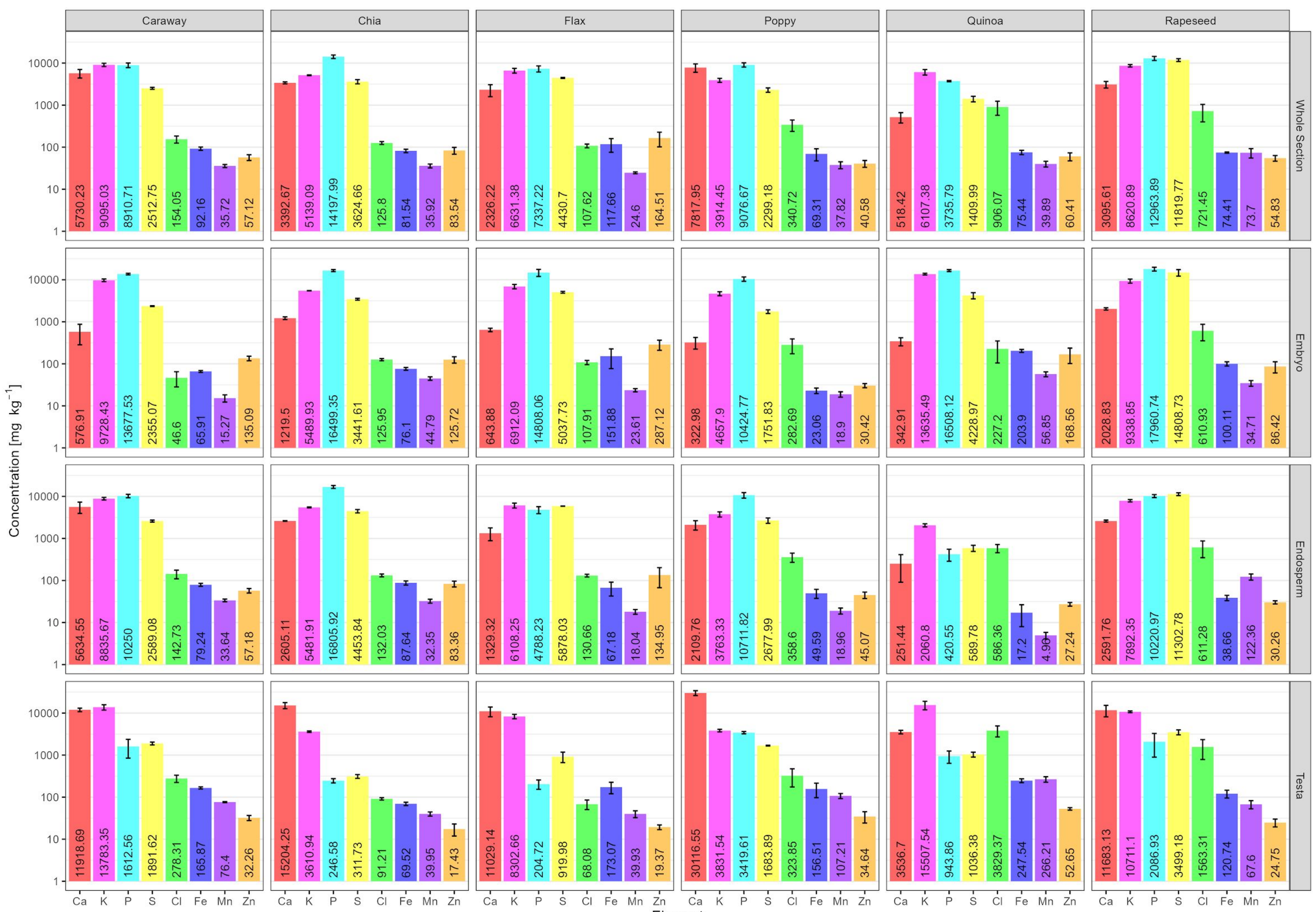

Figure 5: Whole-section and tissue-specific (embryo, endosperm and testa) element concentrations in all six seeds analysed. Note: The concentrations in mg kg^{-1} are displayed on a logarithmic scale.

CONCLUSIONS

- Substantial differences in Ca, Fe and Zn concentrations between species and seed tissues were found.
- In general, whole grain concentrations follow the order: P > K > S > Ca > Cl > Fe > Zn > Mn.
- Of the studied seeds, poppy seed contained the highest concentrations of Ca (allocated to the seed coat, as in other seeds) and the highest concentrations of Fe and Zn were measured in flax seeds (Fe allocated to the seed coat and Zn to the embryo).
- The elemental profiles of the endosperm and embryo in all studied dicot seeds were quite similar, which is in contrast to observations in monocot cereal grains [2].
- Data on essential element distributions in different seeds and their tissues has the potential to support informed decisions in food processing and diets worldwide.

Bibliography

1. P. J. White & M. R. Broadley, New Phytologist. 2009, 182, 49–84.
2. A. Detterbeck, P. Pongrac, S. Rensch, S. Reuscher, M. Pečovnik, P. Vavpetič, P. Pelicon, S. Holzheu, U. Krämer, S. Clemens, New Phytologist. 2016, doi: 10.1111/nph.13987

Acknowledgements

Slovenian Research and Innovation Agency

IC Mikroskopija bioloških vzorcev

This work was supported by the Slovenian Research and Innovation Agency (through research core funding [No. P1-0112, P1-0212 and P1-0034] and project funding [J4-3091]) and the Infrastructural Centre Microscopy of Biological Samples..

ICNMTA 2024
19th INTERNATIONAL CONFERENCE ON NUCLEAR MICROPROBE TECHNOLOGY AND APPLICATIONS