Review

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# A Review of *TRK1* function in *Saccharomyces cerevisiae*

Dorsa Mir Mohammad Sadeghi[1]

[1]University of British Columbia, Department of Botany and Zoology

## Abstract

The *TRK1* gene encodes for Trk1p, which serves as the main potassium ion importer in *Saccharomyces cerevisiae*. Trk1p is responsible for maintaining high intracellular potassium levels necessary for cell growth. Mutant *trk1*Δ cells experience potassium starvation due to a decreased ability to adjust potassium acquisition based on internal and extracellular concentrations, which limits cell growth. Additionally, limited potassium uptake has inhibitory effects on proton expulsion by Pma1 H+-ATPase, resulting in acidic cytosolic conditions, susceptibility to toxic cations, and membrane hyperpolarization in *trk1*Δ cells. This review discusses the known functions of the *TRK1* gene in *Saccharomyces cerevisiae* and investigates how Trk1p expression interacts with other biochemical processes and how cell functions are affected by the *trk1*Δ mutant.

## Introduction

The *TRK1* gene encodes for the Trk1p protein in the Trk1p-Trk2p potassium import system of *Saccharomyces cerevisiae* cells. The protein is composed of four domains, which consist of transmembrane domains and membrane-associated helices (Papoušková et al., 2022), the latter of which function as protein channels for potassium ions. Potassium plays a pivotal role in yeast cells, as Masaryk et al. (2023) found that potassium ions are necessary for membrane potential stability, cell division regulation, stress resistance, cell volume and pH levels. Trk1p is the main potassium ion importer in *S. cerevisiae* (Papoušková et al., 2022) and maintains high intracellular potassium levels needed for yeast growth and to prevent starvation (Masaryk & Sychrová, 2022). It is responsible for the uptake of potassium ions (Kulik et al., 2022) in micromolar concentrations (Papoušková et al., 2022) and maintaining high internal potassium levels for proper cell growth (Masaryk et al., 2023). Trk1p can adapt to varying external potassium levels to maintain *S. cerevisiae* growth (Herrera et al., 2014). The protein can adject potassium acquisition levels depending on internal potassium concentration, extracellular potassium availability, and membrane potential (Masaryk et al., 2023), allowing yeasts to grow in a range of potassium levels (Herrera et al., 2014). Masaryk & Sychrová (2022) found that Trk1p can exist in both low and high affinity modes, ranging between 180 µM to 2.5 mM. The uptake of potassium ions by Trk1p affects intracellular pH, as Trk1p

stimulates Pma1 H+-ATPase activity (**Figure 1**) and proton transport out of the cell (Herrera et al., 2014). This review investigates how Trk1p expression interacts with biochemical processes in *S. cerevisiae*, while focussing on studies about the effects of *trk1*Δ on cell growth and ion homeostasis.

## Cell Growth

Deletion of the *TRK1* gene caused a severe decrease in cell growth and diminished the cell's ability to grow under low potassium availability (Masaryk & Sychrová, 2022; Masaryk et al., 2023). Though the knockout cells were able to grow well in unlimited potassium, those in low (3 mM) extracellular potassium concentrations showed limited growth (Herrera et al., 2014). Additionally, Herrera et al. (2014) found that *trk1*Δ cells were able to adapt and adjust potassium uptake when in a surplus of potassium, but had decreased adaptability to potassium concentrations when potassium availability was low or limited. The capacity to adjust potassium acquisition based on internal and external conditions was measured by the internal potassium levels, and *trk1*Δ cells had significantly lower levels (50%) compared to *TRK1* (80%) cells. Likewise, *trk1*Δ cells experienced a greater decrease in internal potassium levels compared to wild-type cells (Herrera et al., 2014).

## Ion Homeostasis

Papoušková et al. (2022), Lauff & Santa-María (2010), and Navarrete et al. (2010) found that *trk1*Δ

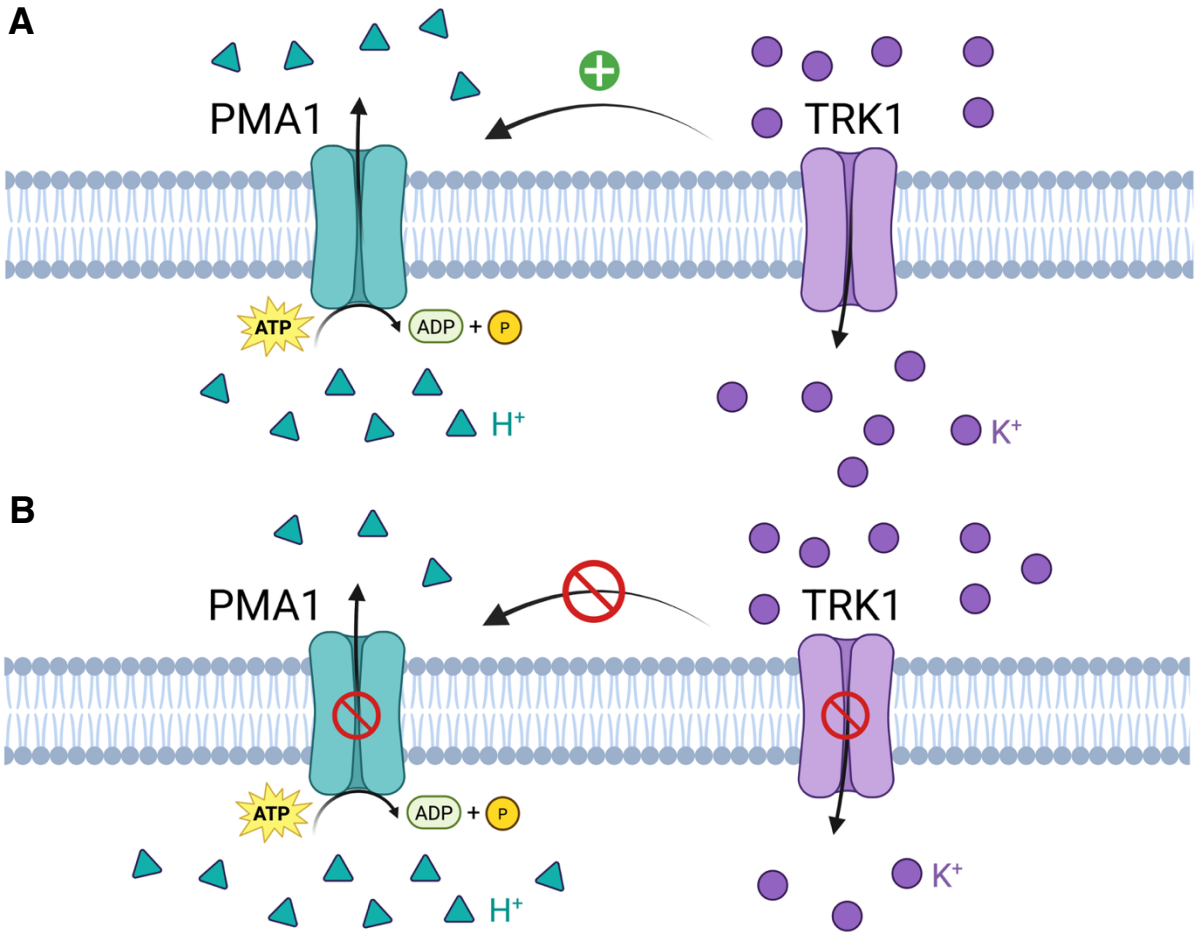


**Figure 1. Potassium uptake by Trk1p stimulates proton expulsion by Pma1 H+-ATPase. A.** Wildtype function of TRK1 causes potassium uptake while stimulating proton expulsion by Pma1. **B.** TRK1 deletion causes potassium starvation and inhibits Pma1 activity, decreasing intracellular pH levels. Arrows depict upregulation. Created with BioRender.com

cells had significantly greater membrane hyperpolarization and cation influx than wild-type cells. The *trk1*Δ cells were more susceptible to toxic lithium and sodium cations (Navarrete et al., 2010), and increased intracellular calcium levels because of potassium deprivation (Lauff & Santa-María, 2010; Papoušková et al., 2022). Additionally, Navarrete et al. (2010) found that *trk1*Δ cells had lower intracellular pH levels compared to wild-type cells, due to reduced proton expulsion by Pma1 H+-ATPase (**Figure 1**). Reduced potassium acquisition in *trk1*Δ cells likely inhibits Pma1 activity. (Navarrete et al., 2010; Papoušková et al., 2022).

## Summary and Conclusion

Many questions regarding Trk1p's affinity switch remain unanswered. When and how Trk1p's affinity for potassium alters, and whether the lone signal for this alternation is potassium, is still experimentally unproven. Though the molecular basis for the affinity switch process is still not clear, researchers speculate that phosphorylation is involved (Masaryk & Sychrová, 2022). Though Herrera et al. (2014) found that potassium deprivation results in proton accumulation in the cell cytosol, the signalling mechanisms that regulate intracellular potassium concentrations and potassium influx remain unclear.

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